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RESEARCH ON GROUND PROPULSION SYSTEMS

HEARINGS

BEFORE THE

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS U.S. HOUSE OF REPRESENTATIVES

NINETY-THIRD CONGRESS

SECOND SESSION

ON

H.R. 10392

JUNE 11, 12, 13, AND 18, 1974

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WITNESSES

RESEARCH ON GROUND PROPULSION SYSTEMS

TUESDAY, JUNE 11, 1974

House of Representatives,
Committee on Science and Astronautics,
Subcommittee on Space Science and Applications,
Washington, D.C.

The subcommittee met in room 2325, Rayburn House Office Building, Hon. James W. Symington [chairman of the subcommittee] presiding.

Mr. Symington. The subcommittee will be in order.

This morning the Subcommittee on Space Science and Applications begins 4 days of hearings on H.R. 10392, a bill to authorize the National Aeronautics and Space Administration to conduct research on ground propulsion systems.

[H.R. 10392 follows:]

93D CONGRESS
1ST SESSION

H. R. 10392

IN THE HOUSE OF REPRESENTATIVES

SEPTEMBER 19, 1973

Mr. BROWN of California (for himself, Mr. MCCORMACK, and Mr. SYMINGTON) introduced the following bill; which was referred to the Committee on Science and Astronautics

A BILL

To amend the National Aeronautics and Space Act of 1958 to authorize and direct the National Aeronautics and Space Administration to conduct research and to develop ground propulsion systems which would serve to reduce the current level of energy consumption.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. (a) Section 102 of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2451) is amended by redesignating subsection (d) as subsection (e), and by inserting immediately after subsection (c) the following new subsection:

"(d) The Congress declares that the general welfare of

the United States requires that the unique competence in scientific and engineering systems of the National Aeronautics and Space Administration to also be directed toward ground propulsion systems research and development. Such development shall be conducted so as to contribute to the following objectives—

"(1) the development of energy conserving ground propulsion systems;

"(2) the development of ground propulsion systems with clean emission characteristics, economical per unit cost, and low per mile energy consumption;

"(3) the improvement of efficiency, safety, performance, and usefulness of ground propulsion systems; and

"(4) the most effective utilization of the scientific and engineering resources of the United States already in existence, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication and waste of effort, facilities, and equipment."

(b) The subsection of section 102 of such Act redesignated as subsection (e) by subsection (a) of this section is amended by striking out "and (c)" and inserting in lieu thereof "(c), and (d)".

SEC. 2. Title II of the National Aeronautics and Space

Act of 1958 is amended by adding at the end thereof the following new section:

"GROUND PROPULSION SYSTEM DEVELOPMENT

"SEC. 207. (a) (1) In addition to its other functions the Administration shall develop ground propulsion systems which are energy conserving, have clean emission characteristics, and are capable of being produced in large numbers at a reasonable mass production per unit cost.

"(2) Such ground propulsion systems must meet or better all air quality standards set by or under the National Emission Standards Act, the Clean Air Act, and the Air Quality Act of 1967, while substantially reducing per mile energy consumption.

"(3) The Administration shall conduct research in alternative energy sources for use in the ground propulsion systems developed under paragraph (1) and shall develop such alternative energy sources for use in those systems.

"(b) In connection with the performance of its functions under subsection (a), the Administration shall evaluate and make a continuing comparative assessment of all ground propulsion systems presently in use, or in a conceptual or development stage.

"(c) There is authorized to be appropriated to carry out this section not to exceed $30,000,000 in the aggregate for the fiscal years 1974 through 1977."

Sec. 3. Section 103 of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2451) is amended by striking out "and" at the end of paragraph (1), by striking out the period at the end of paragraph (2) and inserting in lieu thereof "; and", and by adding after paragraph (2) the following new paragraph:

"(3) the term 'ground propulsion system' means the engine, transmission, or drive, and associated controls, necessary to power automobiles, trucks, trains, buses, and selected light marine vehicles."

The purpose of this bill is to encourage greater utilization of the talent and facilities of NASA in addressing one of the more pressing needs of our society, to wit, the development of more efficient, more economical, and cleaner emission engines for surface transportation systems.

Since the automobile is the principal mode of transportation in our country, the witnesses we have invited to testify on this bill will emphasize research and development of automobile engines, although the language of the bill is broader and encompasses all forms of ground propulsion.

This is the second set of hearings on H.R. 10392. Early in February of this year, the subcommittee heard witnesses chiefly from those Government agencies which have responsibility for the type of R. & D. work contemplated in this bill.

During the next four meetings of the subcommittee, we will take testimony from representatives of the automobile industry, independent developers, consultants and other interested parties.

Before introducing our first witness, I would like to call upon our distinguished colleague from California, Congressman George E. Brown, Jr., the author of the proposal we have under consideration today for a few remarks.

I might say that more than 100 members of the House have joined Mr. Brown as cosponsors of his bill, so it is clear that he has already proved to be a persuasive spokesman for this goal.

Mr. Brown. Mr. Chairman, I very much appreciate your remarks. I am also extremely grateful for your willingness to schedule an additional 4 days of hearings on this legislation. I think these hearings will contribute to making a powerfully persuasive record in support of action by this Congress to help us move further in the direction of energy conservation and nonpolluting motive power for ground transportation.

I have a brief statement which I will not read in full, but I would ask unanimous consent that it be included in the record.

Mr. Symington. It is so ordered.

STATEMENT OF HON. GEORGE E. BROWN, JR., MEMBER OF CONGRESS FROM THE STATE OF CALIFORNIA

Mr. Brown. I would like to comment that I very much regret that we were unable to have with us this morning our distinguished colleague, the junior Senator from California, John Tunney, because Senator Tunney has already, using a slightly different approach to this problem, secured the passage in the Senate of a major piece of legislation which would authorize essentially the same kind of program we are considering in this legislation.

His bill which would provide for a major program of grants and insured loans from the Department of Transportation to enterprises, individuals, or corporations capable of doing research in this field, would have achieved somewhat the same purpose as this legislation; namely, the encouragement of a massive program of research and development in the field of energy conserving and nonpolluting engines for ground transportation.

His legislation and mine differ in their details, primarily in the designation of NASA, in the case of my legislation, to conduct this research whereas in his bill, the designation of the Department of Transportation to administer a grant and loan insurance program. I think it is noteworthy that his legislation has already passed the Senate and is before another committee of this House. I think this indicates the feeling of urgency which many of us have, and which I believe is widely shared in the Congress, that we do make some progress in solving the problems represented by the present system of automotive transportation in this country.

I would hope that as a result of these hearings we could establish a groundwork on which the House of Representatives could determine a policy for pursuing either the course represented by my own legislation, which has been, as you indicated, coauthored by over 100 Members, or a policy which would lead us in the direction of legislation which has already passed the Senate, which was authored by Senator Tunney.

I have no further remarks, Mr. Chairman. I will insert the rest of my remarks in the record.

PREPARED STATEMENT OF CONGRESSMAN GEORGE E. BROWN, JR.

Mr. Chairman, thank you for continuing the hearings on H.R. 10392. I believe the three days of hearings on research on ground propulsion systems held by this Subcommittee last February, and the four days we begin today, will present a clear and overwhelming case for new legislation in this field.

I am somewhat concerned that administrative questions will obscure the fact that the existing ground transportation system in the United States is near collapse. This system is based upon the private automobile, which itself is based upon the energy-consuming and pollution-plagued internal combustion engine. There is a considerable body of thought, which I share, that says the existing structure of the automobile industry is so highly concentrated and anticompetitive that it is capable of preventing changes in our ground transportation system that are perceived as deterimental to the automobile industry. Even if this is not the case, there is serious doubt that voluntary efforts by the automobile industry alone to convert to an alternative technology would succeed, even if such a decision to convert was made.

The history of automobile emissions controls is illustrative of the problem we face. The effects of emissions was known in the early 1950's, but genuine progress in controlling auto emissions did not occur until after passage of the Clean Air Act Amendments of 1970. The progress under that law has now come to a halt because the Congress amended the law this year to freeze the standards for two years, beginning this Fall. The Congress, in an opinion that I did not share, believed that a tradeoff had to be made between emissions controls and fuel economy. Now that that decision has been made, it is appropriate to ask what will be done with that time extension? What progress will the auto industry make in achieving both emissions controls and fuel economy?

The automobile industry, if it wished to avoid government intervention, should have foreseen the need to develop clean and efficient automobiles for mass production. Instead they had to be forced to clean up their machines and they may have to be forced to develop efficient machines. If the achievement of both of these goals at the same time is impossible with the existing internal combustion engine, which is debatable, then we may have to shift to other forms of propulsion.

It is in the area of alternative technologies that the government and the industry have shown the least interest. The greatest progress in alternative technologies has probably been shown by private developers who have managed to do their work with a variety of funding sources. The federal role, as has been demonstrated at our earliest hearing, is fragmented, underfunded and uncoordinated.

Any alternative technology should be considered in the total system in which it will be used. Our entire transportation system needs to be analyzed and restructured. The automobile industry may also need to be restructured to guar-

antee that the public's interest is served. These questions should concern us, but we do not need to wait for them to be resolved to undertake a program of research and development. The testimony on the record clearly establishes that high-risk research and development will not be conducted by private industry. We also know that the R. & D. phase is the most time-consuming aspect of any new technology. This leadtime is being further lengthened by the failure of the government to enter this field.

We all know that we will need more efficient automobiles that are non-polluting. We may have to give up the practice of burning oil in vehicles within the next 20 years. The impact of the automobile upon the American economy is too pervasive and too important to trust the future of our Nation to the decisions made in Detroit. We should prepare for the future, while continuing to improve the present situation as much as possible. Some of the questions I hope we answer in the next four days are:

1. What barriers, technological, financial and institutional, exist in the way of alternative technologies?
2. How can these barriers best be overcome?
3. What should the role of private industry be?
4. What should the role of government be?
5. What can be done to expedite the goals of achieving clean and efficient ground propulsion systems in both the near and the long term?

Mr. Chairman, this concludes my opening statement.

Mr. SYMINGTON. Thank you very much, Mr. Brown. We do regret that Senator Tunney cannot be with us this morning. But, of course, we will have ample opportunity to analyze his legislation.

I would now like to welcome another esteemed colleague to the witness table, Congressman Charles Vanik of Ohio, who I believe has a statement for the committee.

STATEMENT OF HON. CHARLES A. VANIK, MEMBER OF CONGRESS FROM OHIO

Mr. VANIK. Mr. Chairman and members of the committee, I appreciate this opportunity to be here. I am a cosponsor of Mr. Brown's legislation which I think would be of infinite help at this time.

I believe it is time we truly involved NASA on a massive scale in solving some of our earthbound problems. Coming from the Cleveland area I have a NASA installation which I have always thought was the best research-oriented facility that the Federal Government maintained. I never felt that we have fully utilized the fine facilities which were already established by Government.

I think a great deal can be done and I think the expertise of NASA can really help us. The Japanese have a rail institute, as you know, which is working on the development of train engines which can carry loads at 200 miles or more per hour. And at the same time we are buying equipment from the French, the French turbotrains, to do the job for Amtrak.

As the committee knows, I offered an amendment to the NASA authorization bill on April 25 providing for $2 million for hydrogen fuel research. The committee's report mentions some $655,000 for research into the use of liquid hydrogen in aircraft.

In addition, the committee mentioned research presently being conducted into hydrogen fuel for automobiles by the Jet Propulsion Laboratory.

The amendment was accepted, but an effort to carry that forward into the energy research and development appropriation bill failed,

although the Appropriations Committee assured me that greater emphasis would be given in the future to hydrogen fuel research.

Mr. Chairman, I would hope that this bill could be amended to make special and specific mention of the need to consider hydrogen fuel in ground propulsion. As presently worded, the bill seems to give almost all its emphasis to engine improvement, adjustment of drive shafts, the placement of turbine blades, et cetera.

I would hope that this might be increased so we could consider new forms of fuel.

While experiments have been conducted to show us how we could use hydrogen fuel with today's automobiles, I think most people are concerned with the problem of safety. But we could use hydrogen fuel and develop it as an alternative.

Today, hydrogen can be developed by the expenditure and use of a lot of other energy, but we have sources of that, such as solar energy. the thermal gradients in the ocean, wind energy, and fusion energy. There are a lot of energy sources which are abundant and pollution-free and which could be converted into the development of hydrogen energy.

In addition, I would like to call the committee's attention to the fact that I introduced the Fuel Economy Act of 1973, which I have not been able to get through my own Ways and Means Committee. This is simply a tax on inefficient automobiles, the large automobiles, the heavy gasoline consumers which give 6 or 7 miles per gallon. I think inefficient automobiles are something that Americans can no longer afford.

Of course, the industry points to the fact that the pollution devices and other safety features are the primary cause of automobile inefficiency, but the fact of the matter is that other nations are producing automobiles that comply with our air pollution standards and which go as fast as a man ever needs to go—and still get 28 to 30 miles per gallon. And some do better than that. Those automobiles are presently available from foreign manufacturers.

When we talk about people who are derelict in high places in government, I begin wondering about the masters of the automobile industry, who seem to be completely unaware of the energy crisis. As a matter of fact, the chairman of one of the large corporations said last September—the president--and I have the substance of his quote—he said:

> We are going to keep this corporation in the big car field because that is what the American people want.

Well, as you know, with the American automobiles, as with most other products on the American market, people in this country want what they are taught to want and they want what is available. I have been waiting for a long time now—I am almost to the limit of my patience—for an energy efficient American automobile which can meet our pollution standards.

I would hope that your committee would investigate the feasibility of producing more efficient automobiles with existing technology and evaluate the arguments which are made that it cannot be done.

The EPA and the Departments of Transportation and Treasury all came up with potential savings of 1.4 to 2 million barrels of gasoline

within a few years, if existing technology were to be applied to auto manufacturing.

A NASA review of these three studies would be useful. The studies are somewhat different. They have different methodology and they came up with a different range of figures.

In addition, none of these studies developed a great deal of public exposure. A NASA study could show how our automobiles could be made more efficient and would put an end to the endless attempts to blame poor mileage on the EPA clean air regulations.

Mr. Chairman, I would like to stress several other advantages of the fuel economy excise tax proposal which I would hope you could support, in addition to the Brown legislation.

Such an excise tax could provide aggressive research, development and construction programs in transportation. A recent study by the Department of the Treasury estimated that a fuel economy excise tax could raise $11.5 billion over 6 years.

The revenue from the tax would decline as automakers responded with more efficient cars. Although revenue would be funneled into the General Treasury, it is only logical to dedicate a major portion of these funds to developing new transportation technologies. We have not made any progress in our efforts to establish a trust fund for this purpose.

When I first proposed the fuel economy bill, it was my hope to place at least a portion of these revenues in an energy research and development trust fund.

I sincerely believe that if we had put a trust fund into effect as soon as the crisis started, if we had had the flexibility, we would have had about $5 billion in that fund already.

One other point I want to make. The fuel efficiency amendment would have another benefit. In addition to saving energy—1 to 1.5 million barrels per day by 1980—we would be buying time to develop transportation alternatives.

Mr. Chairman, it would be the height of folly to continue to trust our transportation future to the narrow interests of the auto industry. There is no effective alternative to congressional leadership.

Both a fuel economy tax and an aggressive transportation research program can provide the keystone for an innovative Federal transportation policy. I just want to say one other thing today. I think your committee has generally been very restrained in moving forward in setting forth the funding and requesting the funds which are necessary to do this work. I want you to know that at this very moment they are granting contracts "harum-scarum" in the Energy Office to almost anyone who walks in. It is almost like a Hecht's basement sale.

I do not believe they are all concerned about the money which is being spent. I think most of it is oriented to the petroleum and coal industry, completely ignoring these alternative forms of energy.

It seems to me that when we look at the record and see what tremendous sums are currently being spent for research in the coal and in the oil area and how little is spent in the rest of the spectrum that we can see—I think it is a definite effort to compel our Government to concentrate on these two sources to the detriment of the many alternatives which are available in the other fields. I look upon Mr. Brown's legislation and the work of your committee as an alternative

balance. I think if anything is going to be done really with respect to the other forms of energy that it will have to be done by your committee and through the NASA structure, because I just do not believe that these alternatives are going to receive very much consideration by those who are disbursing the millions and millions of dollars coming out of the Federal Energy Office.

[The complete prepared statement of Congressman Vanik follows:]

TESTIMONY OF CONGRESSMAN CHARLES A. VANIK (OHIO) BEFORE THE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS OF THE HOUSE SCIENCE AND ASTRONAUTICS COMMITTEE

Mr. Chairman, Members of the Committee:

I appreciate this opportunity to present testimony on H.R. 10392, a bill to conduct research and to develop ground propulsion systems which would serve to reduce the current level of energy consumption.

I believe that it is time that we truly involved NASA—on a massive scale—in solving more of our earth-bound problems. Coming from the Cleveland, Ohio area, I am aware of the enormous potential of NASA scientists, engineers, and technicians to help solve pollution and energy problems. As you know, the NASA Lewis facility near Cleveland has been substantially engaged in research on air pollution, noise pollution, and new forms of energy. Much of our new research on wind power is being conducted out of Lewis.

Yet I believe that a great deal more should and can be done. Certainly one of the most important areas to use NASA expertise is in ground propulsion systems research and development. The Japanese, for example, have a Rail Institute and have developed train engines that can carry loads at two hundred miles per hour and more. Yet the United States has just spent $18 million to buy French turbo train engines for Amtrak. It certainly seems to me that if we can provide leadership in space, we can provide a good deal of leadership in ground transportation and NASA can help lead the way.

As the Committee knows, I offered a floor amendment to the NASA authorization bill on April 25th providing a specific $2 million for hydrogen fuel research. The Committee's report to the NASA authorization bill mentioned some $655,000 for research into the use of liquid hydrogen in aircraft. In addition, the Committee mentioned research presently being conducted into hydrogen fuel for automobiles by the Jet Propulsion Laboratory.

The amendment was accepted, but an effort to carry that forward into the Energy Research and Development Appropriation bill failed, although the Appropriations Committee assured me that greater emphasis would be given in the future to hydrogen fuel research.

Mr. Chairman, I would hope that this bill could be amended to make special and specific mention of the need to consider hydrogen fuel in ground propulsion. As presently worded, the bill seems to give almost all its emphasis to engine improvement, adjustment of drive shafts, the placement of turbine blades, etc. I would hope that the bill would make clear the fact that new engines and adopted engines which can use new forms of fuel would also be supported by this legislation.

While experiments have been conducted showing how today's automobiles can be adopted to hydrogen fuel, a number of problems must be solved. In particular, I think it is important that the committee bill stress the importance of safety. When most Americans think of hydrogen as a fuel, they recall pictures of the Hindenburg exploding and burning over Lakehurst, New Jersey. Hydrogen will not be accepted as a common fuel until people know and believe that it can be used safely.

Today, hydrogen can generally only be obtained by the expenditure of a large amount of energy. But in the near future, I believe that the use of solar energy, including the use of thermal gradients in the oceans, and fusion energy can make a hydrogen fuel society possible. We should prepare now to know how to use pollution-free hydrogen in our ground propulsion systems.

Mr. Chairman, in addition to stressing hydrogen fuel use and safety, I would like to make brief reference to other proposals designed to increase the efficiency of automobiles.

In May of last year, I introduced the Fuel Economy Act of 1973. Under this legislation, the automobile industry for the first time would be provided an incen-

tive to make their cars efficient. The technique for creating this incentive is simple: a Federal excise tax would be imposed—beginning in model year 1977—on all new cars with an efficiency under 20 miles per gallon. The tax would be graduated so that the more inefficient cars would pay a higher tax. With this tax in place, the Big Four would have a direct and continuing incentive to improve the fuel efficiency of their automobiles. Other members have introduced bills simply requiring that autos meet a certain efficiency level by a certain date.

I would hope that the Committee could stress the importance of such proposals. Perhaps reference could be made to the need for these bills in the Committee's Report on H.R. 10392. As an alternative, perhaps H.R. 10392 could be amended to mandate a scientific study or report by NASA on the feasibility of more efficient automobiles. Specifically, as the Committee knows, there have been three major Federal agency reports on automobile efficiency. EPA, Treasury, and the Department of Transportation all came up with potential fuel savings of 1.4 to 2.0 million barrels of gasoline per day within a few years if existing technology was applied to auto manufacture. A NASA review of these three studies would be useful because the studies used somewhat different methodologies and did come up with a range of figures. In addition, none of the studies received a great deal of public exposure. A NASA study could show how our autos could be made more efficient—and would put an end to the endless attempts to blame poor mileage on EPA Clean Air regulations.

Mr. Chairman, I would like to stress several other advantages of the fuel economy excise proposal. Such an excise tax could provide a convenient and responsible way in which to fund an aggressive research, development and construction program in transportation. A recent staff study by the Department of Treasury estimated that a fuel economy excise tax could raise over $11.5 billion over six years. The revenue from the tax would decline as the automakers responded with more efficient cars. Although revenue from this tax would be funneled to the general revenues of the Treasury, it is only logical to dedicate a major portion of these funds to developing and constructing new transportation technologies. We may want to consider the establishment of a trust fund for this purpose.

In addition, the fuel efficiency amendment would have another benefit. By saving significant amounts of energy—between 1 and 1.4 million barrels a day by 1980—we will be buying time to explore and develop new transportation alternatives.

Mr. Chairman, it would be the height of folly to continue to trust our transportation future to the narrow interests of the auto industry. There is no effective alternative to congressional leadership. Both a fuel economy tax and an aggressive transportation research program can provide the keystone for an innovative Federal transportation policy.

Mr. SYMINGTON. Thank you very much, Mr. Vanik.

Mr. Downing?

Mr. DOWNING. Thank you, Mr. Chairman. It is always a pleasure to have our friend and colleague from Ohio with us. I think you have made an extremely fine statement. What is the source of hydrogen?

Mr. VANIK. It is derived from water, H_2O. You separate it from water. It is as abundant as water. The trouble is it takes energy to create hydrogen fuel, but if we can develop low cost available sources of energy through solar energy or through tidal or thermal gradients to do it, then we develop a low-cost source of energy to develop the energy we need.

It is a conversion process. Hydrogen energy is a secondary fuel.

Mr. DOWNING. Do we have the technology now to extract hydrogen from water?

Mr. VANIK. Yes. We are doing it, but not economically. The whole problem is one of economics, but I think there is a solution to the problem. It can be done in the conventional automobile. It will burn like gasoline. It has to be stored differently. There may be a different type of tank, but the present engine can burn hydrogen fuel and has demonstrated the capacity to do it.

Mr. DOWNING. Mr. Chairman, a little aside.

The witness and I bought the same type of American automobile in 1965 and are still operating it today. And although we are polluting the atmosphere by today's standards, we would not give up this 1965 automobile and will not until it falls apart.

Mr. VANIK. I am maintaining it with vigilance and care, but on my 1965 Ford I get 24 to 25 miles per gallon with a lot of safety. It is a heavy car. It is a straight line six-cylinder engine. And it is perfectly wonderful. The industry has all of the research. They have all of these engines in storage in their museums, and all they have to do is bring out a 1938 motor and put some air pollution devices on it and we can get about 24 miles to the gallon. But that would change the dynamics of the high-compression engine in which there is a considerable investment. They have to amortize that investment. So I would recommend to our automobile makers that we sell those cars to the Saudi Arabians.

Mr. DOWNING. You are not thinking of putting any pollution control devices on your 1965 automobile, are you?

Mr. VANIK. I do not think it pollutes that much. I am reminded of some of the 1914 Allis-Chalmers equipment which was tested and proved to meet the pollution standards of today. It was just a different kind of engine. I think the tremendous contribution to pollution came with the high-compression engine.

I think it is the sort of thing we ought to do. We ought to submit our automobiles to an EPA test. I do not think they would rate as badly as you might suspect. Of course, perhaps with an older car you are probably burning cheaper fuel and low-cost oil. But my oil consumption is absolutely negligible in my automobile, just as low as it is in my new automobile.

Mr. DOWNING. Thank you.

Mr. SYMINGTON. When you get ready to sell those cars let the committee know. [Laughter.]

Mr. DOWNING. We will not sell them.

Mr. SYMINGTON. Regarding your reference to hydrogen fuel development, I would like to call on Mr. Brown, because I know he has high on his list of priorities the development of hydrogen fuel propulsion. We visited the Jet Propulsion Laboratory in California to see their experiment. I believe the Brown bill is broad enough to include such things.

Mr. Brown?

Mr. BROWN. Thank you, Mr. Chairman. I am glad you made that point about the bill. I construe the bill to be broad enough in its language to include a NASA mandate in the field of fuels as well as in the mechanics of engines. And if it is not, I assure the gentleman we will broaden it so as to do that.

Mr. VANIK. Do you have a specific reference to the language which would do that? That might be section 207, would it?

Mr. BROWN. Yes.

Ground propulsion systems which are energy conserving with clean emission characteristics and are capable of being produced in large numbers. The administration shall conduct research on alternative sources for use of energy systems.

Mr. VANIK. I was just hoping that hydrogen fuel would be mentioned because it is adaptable to the present engines. Maybe you could do that in legislative history or some other way.

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Mr. BROWN. We can do that or we can cite it as an example of alternative fuels. I should point out to the gentleman, as the chairman indicate, that part of the research now being done by NASA is in the field of hydrogen fuels.

The experiment which we witnessed at the Jet Propulsion Laboratory was a new method for onboard generation of hydrogen from gasoline. A portion of the gasoline would be converted to hydrogen which would then be injected into the engine with consequent improvements both in mileage and pollution. There are several ways of generating hydrogen. One is the one which you mentioned from water by electrolysis or other means.

OTHER METHODS EXIST

One of those other methods is being used at JPL. And the cost factor is reasonable, I might say so.

I am impressed by your testimony, Mr. Vanik, and particularly the last paragraph which I think capsulizes the problem which faces us here. There is no effective alternative to congressional leadership, as you say.

Our problem, I am sure you would concur, is that the broad policy aspects involving meeting our energy situation as well as many of our other situations are fragmented into an number of committees. Your own bill having to do with an excise tax on fuels I think should be a key ingredient to any overall energy policy.

There should also be a role for the Department of Transportation and a role for the research and development expertise of Lewis Laboratory in your own district, and the other facilities of NASA. But each of these separate phases of the problem is being considered by a different group of Congressmen with different ideas. It has not been possible to bring these together into a policy package.

Now, as I said at the beginning, it is my hope that by establishing a record here which lays stress on the overall policy needs, we may be able to generate in part the momentum to have the Congress act responsively as I believe they should.

I am not as familiar with the Lewis facility as you are, but it has been reported to me that they are engaged in a number of types of research which would be applicable to the development of improved engines, including the external combustion engine.

Mr. VANIK. Right, fuels research for external combustion engine.

Mr. BROWN. I will just reiterate, because you mentioned it several times, that if the bill is not sufficiently broad in its language to include the development of alternative fuels. I feel sure the committee would want to do that, Mr. Vanik. And we will try to clarify that language.

Mr. VANIK. I might say, while I still have this opportunity here with my colleagues, that I would like to address your attention to the fact that we are dealing with energy windfall taxation later next week. I am endeavoring to increase the reveneue from that legislation by several billion dollars. I feel that really it is just unfortunate that whatever we create does not go into a trust fund to help solve the energy problem. I have problems selling my colleagues on the Ways and Means Committee on the concept of a trust fund to develop the

sources of money for this kind of research. I think the money ought to be earmarked, and I do not think we will really make any real progress in solving the energy problem unless we do earmark somehow or another substantial sums of money to solve the problem. I would say your legislation is conservative on its money request. I think you will probably find the House, and the Congress as a whole receptive to spending more money for what you seek to do because we have to do it to solve the problem.

Mr. BROWN. I might say, Mr. Vanik, that the bill by our colleague, Senator Tunney, does provide for substantially more money than we are considering here.

Let me ask you just one general question having to do with the mechanics here. We have heard earlier testimony from administration witnesses who generally take the view that insofar as this relates to energy conservation in that large component of our society which deals with transportation that it is a function more of the proposed ERDA organization, the Energy Research and Development Administration, which is in the process of being established.

I do not think the committee would raise any major objections to this. We have handled other types of bills to which the same objection was raised by inserting a clause to the effect that when ERDA is established the lead function would be transferred to ERDA with, of course, the basic research still being done in the NASA laboratory. Would you see any problems with this kind of approach?

Mr. VANIK. My only fear about the ERDA structure is that it is pretty much weighted to the development of energy based on nuclear, oil, and coal. This is the whole problem with it. It seems to be designed in that direction. Those are the propelling forces. I feel that within government we can have competing programs. I think this is the way you get results when you can see which agencies are oriented to doing a more flexible job. My concern about the ERDA organization is that it is oriented too much to the traditional answers to the problems. I do not know how you can change that by its basic structure. What is being put together in ERDA will be heavily weighted toward doing the conventional things and putting reliance on conventional forms of energy rather than having the ingenuity and the flexibility to move into new energy forms, as I think we can under your legislation and with the NASA program.

Mr. BROWN. There is one other thing I would like to ask you to comment on. There is another kind of weighting which is beginning to bother me. We have had indications that the Office of Management and Budget is opposed to a Federal role in this whole field.

Mr. VANIK. We have to change that office. I do not know how you can do it.

Mr. BROWN. Not only have they suggested that a very limited amount of existing funds which are going into research on propulsion systems and new fuels is unnecessary but they have even tried to eliminate the research which I mentioned earlier at the Jet Propulsion Laboratory suggesting that if it were to be continued it would be funded from private contributions of the automobile companies or be done by them.

What is your reaction to that kind of an attitude?

Mr. VANIK. I do not think it is a realistic solution to our problems, and I think we have to do whatever we can to bring our influence to

bear on the Office of Management and Budget. I sometimes feel there is a hostility in Government to solving problems. And that Office has been a very difficult one to deal with. I think we have to put some congressional mandates on that Office. It is the fourth branch of Government. We have to put some restraining forces on it. I think that Office was designed to make Government more efficient and not to mold policy as heavily as it does.

It has more influence and power than 535 Members of Congress. I frankly feel that weighting that Office with that much power over policy is a very serious matter which has to be corrected in the new Congress and as we move toward more congressional leadership.

It very often operates as an obstruction to congressional planning and desires to develop progressive legislation.

Mr. BROWN. Just one final comment I would like to make. The most energy efficient form of human transportation is the bicycle. And I want to assure you that under this legislation we could conduct research on improved bicycles.

Mr. VANIK. I want to tell you about a problem which has occurred in my office. One of my interns the other day was riding his bicycle in Georgetown and he got the wheel into a car track out there. He is now in the hospital in rather critical condition. So that is another aspect of bicycle riding. It frightens me to put many bicycles on the streets which may be hazardous.

Mr. BROWN. This emphasizes the problem. We need to design a system of transportation which is safe for bicycles.

Mr. SYMINGTON. Just to recapitulate: The main reason we are having these hearings, and the reason for many other similar hearings on the Hill stems from the realization that in the 1980's the disparity between our fuel needs and fuel supplies, especially from the Middle East, will be very great. Evidently dependence on the Middle East will be very great regardless of the steps we take. We want to minimize that dependence, and one of the ways to do it is to get energy alternatives, and the other way is to stop the waste of fossil fuels.

So we asked the Department of Transportation what they thought of Mr. Brown's bill, and what they thought their obligations were with respect to the automobile industry. They testified they think it is up to Detroit to make the innovations necessary to conserve fuel. That was the thrust of their testimony.

We read your testimony and you seem to say that it is folly to continue to trust our transportation future to the narrow interests of the auto industry. The Department of Transportation apparently believes that the automobile industry even in its narrow interests will somehow address itself to the needs of the 1980's. You are skeptical. I might add that we are skeptical. You have suggested one approach which might stimulate the auto industry to consider this type of research, and that, of course, is a tax on the inefficient automobile. So perhaps that ought to be restudied in the Ways and Means Committee. In the meantime, of course, we will have a chance to hear from the auto industry as to how they would propose to analyze the problems to handle these problems in coming decades.

Mr. VANIK. Thank you very much Mr. Chairman.

The country was dependent on whale oil, as you know, in the early part of the last century. Someone sent me a story about it. When the

price for whale oil went up to the moon, we developed the use of petroleum as an internative and destroyed the need for dependency on whales. I feel the same thing will happen to petroleum. I am quite satisfied that we are being driven to developing an ingenuity which will make the oil of the Middle East irrelevant.

I am certain—just as certain as I am here—it may not happen in my time and it may not happen for the comfort of the people in this generation or perhaps the next, but I do think that those people who feel the world will be permanently dependent on their petroleum supply may some time be awakened to the fact that they have an asset that is not quite as valuable as they thought. I am sure we can develop alternatives.

Mr. SYMINGTON. Tne question of relevance is only relevant for the next few years, and then it will all be gone. So we have to think about that. I am sure that is within your lifetime, Mr. Vanik.

Mr. VANIK. I hope so.

Thank you very much, Mr. Chairman.

Mr. SYMINGTON. Our next witnesses are Mr. Carl E. Nash and Mr. Clarence M. Ditlow of the Public Interest Research Group, a Washington, D.C., organization which is headed by Mr. Ralph Nader. Welcome to you gentlemen. I understand Mr. Nash has prepared a statement. You may proceed.

STATEMENT OF CARL E. NASH AND CLARENCE M. DITLOW

Mr. Chairman and distinguished members of the House Subcommittee on Space Science and Applications, we appreciate being invited to present our views on H.R. 10392. I am Carl Nash, a physicist, and this is Clarence M. Ditlow, an attorney. We are members of the Public Interest Research Group, an association of lawyers and scientists founded by Mr. Ralph Nader in 1970.

The automobile and ground transportation vehicle industry is one which can claim few technological advances outside those that make production of such vehicles more efficient and economical. Since the 1930's, the only important innovations that have been incorporated into new cars are air bags for occupant crash protection, catalytic type exhaust emission converters, and stratified charge piston engines. The first of these was introduced on a very limited basis this year by General Motors, and the second will be found on most domestic cars to be marketed this fall. The third will be found only on the Japanese Honda Civic next year. The Wankel engine configuration that is currently used in foreign cars was actually invented in the 1930's although the first practical Wankel-powered car was not produced until the 1950's. None of these innovations was invented or given initial development by one of the four major automakers in the U.S.

The automobile of today is different in degree but not in kind from the automobile of 1940. This technological sameness is a reflection of the structure of the scientific and engineering functions of the auto companies. Compared with most other major U.S. industries, the auto industry puts a very small part of its income into research and basic development work. The industry has also traditionally shifted the burden of such work on to its suppliers so that they have made the important advances in electrical systems, tires, glass, occupant restraint systems, and brakes. It is only because General Motors owns so many of its own suppliers that GM can be credited with a fair amount of this research and development work. The Ford Motor Company is the only one of the big four that operates a major laboratory devoted to basic science, and that laboratory is small compared with the major scientific laboratories such as those of the Bell system or General Electric.

Even mass transit vehicles of today, often touted for their technological advances, are not so different from those of decades ago. The new Metrobuses are as little different from city buses of the 1930's as are today's cars from the cars of the 1930's. The Bay Area Rapid Transit system still uses steel rails, steel wheels, and electric motors just as did subways of fifty years ago. The control

system for the BART system borrowed heavily from the technology of the elevator industry, and then has been shown to have a critical defect in the detection of the position of stationary trains.

To get a standard of comparison for technological development, one need only look at the space program or the television and electronics industry.

Yet the auto companies do spend a considerable amount of their income on superficial redesign of their products and on plant conversion. In 1973, for example, Chrysler spent $400 million on tooling and equipment for the redesign of its full size car lines,[1] cars that have since become a glut on the market. This kind of expenditure is typical of the money spent on advancing the game of trivial product differentiation and supercilious model development to artificially stimulate consumer demand.

The annual style change is even more insidious than it first appears because it also serves as an entry barrier to new competition. Bradford Snell has estimated that due to the annual style change and the need to produce around 300,000 similar vehicles to achieve economies of scale, the investment needed to enter the domestic auto market is $779 million of which $724 million would be needed to provide annual style change capability.[2]

Recent plant conversions for the production of smaller cars have been accomplished at a cost of between $50 and $100 million each with the current orgy of such conversions estimated to cost between $4 and $6 billion.[3]

Yet this industry claims to spend money on the order of millions and tens of millions of dollars each year for fundamental research and development work into new safety, emission control, and new power plant technology. Much of this work, such as on the Wankel engine, stratified charge engine, turbines, and Stirling engine is based on old or borrowed technology, sometimes paid for at a cost in excess of the probable cost of original research and development work.[4]

The industry's inflated quotations on the amounts spent on emission controls and safety account for money spent on specific applications and emissions and safety certification work, almost none of which advances the technology significantly. The lion's share of this development work is aimed at improving fuel economy, drivability, comfort, and reduced costs consistent with minimally meeting the federal standards. For example, General Motors projected expenditures of 350.7 million dollars on emission control research and development for 1974. Yet GM's claimed expenditures for alternative engine systems is less than 10 percent of this total. Ford Motor Company followed in lock step spending less than 8 percent on alternative engines out of a budget of 340.1 million dollars in 1973. Chrysler Corporation brought up the rear with total emission controls expenditures of 46.5 million dollars in 1974 of which 3.9 million dollars went to alternative engine research.[5]

In the emission control area, the Justice Department disclosed in 1969 the real reason for the domestic auto industry's delay in cleaning up exhaust and other emissions. The Department filed an antitrust suit against the domestic car makers and their trade association, the Automobile Manufacturers' Association (now the Motor Vehicle Manufacturers' Association), for conspiring to restrain the development and marketing of auto exhaust control systems since 1953.

The evidence brought together prior to this suit by a Los Angeles Grand Jury outlined the cross licensing agreement and other close associations between these so-called auto competitors that forged this illegal, united front of inaction. The Grand Jury wanted to indict the companies but the top Antitrust Division officials over-ruled their own trial attorney and filed a civil suit instead in January 1969.[6] In September 1969, the domestic auto makers entered into a consent

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1 Irvin, Robert, "Big 4 Get Message," Washington Star-News, December 28, 1973, p. D–7.

2 Snell, Bradford, "Annual Style Change in the Automobile Industry as an Unfair Method of Competition," *the Yale Journal*, Vol. 80, No. 3, January 1971, p. 567, 588.

3 Anon., "Detroit Tries to Shift Gears," "*Christian Science Monitor*, May 21, 1974. Green, John, "Those Swingin' Plants," *Ward's Auto World*, April 1974, p. 29.

4 GM, for example, paid $50 million for the rights to the Wankel engine configuration, yet this engine now appears to be considerably less promising than was originally thought because of fuel consumption and emissions problems. Considering inflation, this amount is about double the four year appropriation that would be authorized under HR 10392.

5 These figures are taken from emission control expenditure records from GM, Ford, and Chrysler 1976 emission standards suspension applications before the Environmental Protection Agency, copies of which are submitted for the record.

6 On May 18, 1971, Congressman Phillip Burton inserted the confidential memorandum of the trial staff of the Antitrust Division of the Justice Department recommending to the Attorney General that criminal charges be brought against the American auto manufacturers for conspiring to restrain development of a pollution-free motor vehicle into the *Congressional Record*. A copy of the document is submitted for the record.

agreement with the government agreeing never again to engage in such a conspiracy.[7]

According to an Environmental Protection Agency memorandum, the automotive air pollution resulting from this conspiracy cost the American government $2.7 billion.[8] The cost to the American public was even higher. The continuing absence of more efficient and cleaner alternatives to the traditional piston type internal combustion engine causes the damages to mount to this day. According to the Department of Justice, the domestic auto manufacturers rejected the cheaper, more fuel economical and lower emission stratified charge engine at least 15 years ago:[9]

> For instance, in the late 1950's Ralph Heins, inventor, developed and patented a stratified charge engine which reduced hydrocarbon, carbon monoxide, and oxides of nitrogen emissions, while at the same time effecting a savings in gasoline consumption. Moreover, the stratified charged engine would replace the conventional engine with little or no additional cost to the consumer. The development of this engine was publicized generally so that the automobile manufacturers knew of its existence and what it would do. In fact, Victor G. Raviole, former executive director of the Ford engineering staff, stated on several occasions in the early 1960's that the major automobile companies were investigating such an engine and on one occasion predicted that it might be ready for production before 1965. However, the automobile manufacturers have evidenced little faith in this approach and no such engine has been produced by any of them.

If the domestic auto industry had converted to the stratified charge engine, the consumer wouold have saved $120.60 for the emission controls on 1974 cars according to the National Academy of Sciences and at the same time would have enjoyed 12 percent better fuel economy according to the EPA.

This fall, the stratified charge engine with its various consumer and environmental benefits will appear on the American market. The only catch is that the engine had to go to Japan before coming home to America. It is Honda, a small Japanese company, that has spent $50 million for research and development on the stratified charge engine. In addition, Honda has spent $100 million t convert its existing engine line to build stratified charge engines and to add another stratified charge engine production line.

A specific example of the relaxed approach to new engine development can be found in Chrysler's turbine work. Chrysler claims that it first began to work on turbine power plants for automotive applications in 1946. Their first working model was constructed in 1954, and in 1963, Chrysler was sufficiently confident of its success that it built and loaned to various members of the public fifty turbine powered cars. By its own count, chrysler has produced six generations of turbines. However, it has required a $6.4 million grant from the Enviornmental Protection Agency to stimulate further development work. It seems incongruous that the federal government should have subsidize research and development work that will probably be in the self-interest of this multibillion dollar corporation. By comparison, GM and Ford participated in the Department of Transportation's experimental safety vehicle program on a one-dollar contract basis.

Nonetheless, there may be a place for direct federal stimulus to the development of alternative power systems for land vehicles. Small research and development companies such as Steam Power Systems, about which you heard on February 6, 1974, and enterpreneurs like William Lear and the Carter family from whom you will hear on June 18, may, without the historical encumbrances of the auto makers and traditional automotive engineering, be able to make the breakthroughs necessary to achieve the revolutionary design changes that will be necessary for the continued co-existence of man and his transportation systems.

I am skeptical, however, about the auto companies' ability to respond to this challenge without external stimulus which could cause one or more of the companies to break ranks with the bailing wire approach to safety and emission controls demonstrated by the industry during the last decade.

H.R. 10392 proposes that the National Aeronautics and Space Administration be given the authority to carry out research and development work on alterna-

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[7] A copy of the consent decree is submitted for the hearing record along with the Justice Department's press release and Mr. Ralph Nader's letter of September 15, 1969, to Assistant Attorney General Richard W. McLaren criticizing the consent settlement.

[8] Copies of this document and related memoranda are submitted for the hearing record.

[9] Confidential Department of Justice memorandum, supra, 117 Cong. Rec. H4072 (daily ed., May 18, 1971).

tive propulsion systems. We think, however, that before this legislation is passed, serious consideration should be given to vesting that authority in either the Department of Transportation or the Environmental Protection Agency. Each of these agencies has had considerable experience in contracting work with private firms as well as with the governmental agencies such as NASA and the National Bureau of Standards. Such authority falls more naturally in the mission of either the EPA or the DOT than with the NASA. In any event, I would assume that a majority of the work carried out under the authority of this Bill could be carried out under contract rather than in government facilities.

The characteristics of ground propulsion systems that would be encouraged should go beyond those specified in H.R. 10392. There are five primary areas in which goals should be specified: (1) use of low grade or easily obtainable fuels, (2) economy of production and operation (including fuel use in a variety of operating moaes, lubricant and coolant use, a high power-to-weight ratio and power-to-size ratio, use of common or inexpensive construction materials, and durability and ease of repair), (3) low emissions as an inherent characteristic, (4) safe operating parameters, and (5) flexibility to operate in a wide range of conditions and power demands.

The use of Diesel oils in power plants has the dual advantage of requiring fuels that are less refined (which consequently produce more energy per barrel of crude oil at lower cost) and of having an inherently reduced risk of fire in a crash or other mishap. In addition, engines that use ethanol from the enzymatic hydrolysis of cellulose wastes should be encouraged in the event that the process becomes commercially feasible in the near future.

High power-to-weight and power-to-size ratios are necessary to obtain the most economical and efficient space utilization in personal transportation. The demands of flexibility in speed and power output are probably the reasons for the dominance of the piston type internal combustion engine in the past.

The problems that will confront any agency that undertakes the mission to develop a viable alternative to the internal combustion engine, the Diesel bus and truck engine, and the electric motors of trains and subways, will be manifold. Consideration must be given to the variety of thermodynamic cycles: Otto, Diesel, Rankine Stirling, and others. In addition, the methods of utilizing these cycles include piston type engines, rotary designs of various types, and turbines. Finally, the combination of an engine and the means of translating engine motion into vehicle motion can be mechanical, hydraulic, electrical, and even magnetic, and may involve energy storage devices such as flywheels, batteries, and even storage of fuels manufactured in the engine.

It is tragic that the industry that will benefit most from the fruits of H.R. 10392 has shown so little interest in privately carrying out or funding the type of research envisioned in that bill. Perhaps the artificial competition that will be spurred by the passage of H.R. 10392 will have the additional side effect of stimulating these giants into additional complimentary research and development work. Thank you.

STATEMENT OF CARL E. NASH AND CLARENCE M. DITLOW

Mr. Nash. Thank you, Mr. Chairman and Congressman Brown. We appreciate being invited to present our views on H.R. 10392.

I am Carl Nash, a physicist, and with me is Clarence Ditlow, an attorney and an environmentalist specialist.

We are members of the Public Interest Research Group, an association of lawyers and scientists founded by Mr. Ralph Nader in 1970.

The automobile and ground transportation vehicle industry is one which can claim few technological advances outside those that make production of such vehicles more efficient and economical. Since the 1930's, the only important innovations that have been incorporated into new cars are airbags for occupant crash protection, catalytic-type exhaust emission converters, and stratified charge type piston engines. The first of these was introduced on a very limited basis this year by General Motors, and the second will be found on most domestic cars to be marketed this fall. The third will be found only on the Japanese

Honda Civic next year. The Wankel engine configuration that is curmently used in several foreign cars was actually invented in the 1930's, although the first practical Wankel-powered car was not produced until the 1950's. None of these innovations was invented or given initial development by one of the four major automakers in the United States.

The automobile of today is different in degree but not in kind from the automobile of 1940. This technological sameness is a reflection of the structure of the scientific and engineering functions of the auto companies. Incidentally, the simpler automobiles, the six-cylinder ones with standard transmissions and so forth, are not that much different from the automobiles of the 1920's. Compared with most other major U.S. industries, the auto industry puts a very small part of its income into research and basic development work. The industry has also traditionally shifted the burden of such work onto its suppliers so that they have made the important advances in electrical systems, tires, glass, occupant restraint systems, and brakes. It is only because General Motors owns so many of its own suppliers that GM can be credited with a fair amount of this research and development work. The Ford Motor Co. is the only one of the Big Four that operates a major laboratory devoted to basic science, and that laboratory is small compared with the major scientific laboratories such as those of the Bell System or General Electric.

Even mass transit vehicles of today, often touted for their technological advances, are not so different from those of decades ago. The new American Motors-built Metrobuses are as little different from city buses of the 1930's as are today's cars from the cars of the 1930's. The Bay Area Rapid Transit System still uses steel rails, steel wheels, and electric motors just as did subways of 50 years ago. The control system for the BART system borrowed heavily from the technology of the elevator industry, and then has been shown to have a critical defect in the detection of the position of stationary trains.

To get a standard of comparison for technological development, one need only look at the space program or the television and electronics industry. And perhaps the most startling recent development has been the miniaturization and cost reductions of calculators. Now you can get fancy pocket scientific calculators for under $100, whereas they cost thousands of dollars and were much larger only a few years ago.

Yet the auto companies do spend a considerable amount of their income on superficial redesign of their products and on plant conversion. In 1973, for example, Chrysler spent $400 million on tooling and equipment for the redesign on its full size car lines, cars that have since become a glut on the market. This kind of expenditure is typical of the money spent on advancing the game of trivial product differentiation and supercilious model development to artificially stimulate consumer demand.

The annual style change is even more insidious than it first appears because it also serves as a basic entry barrier to new competition. Bradford Snell has estimated that due to the annual style change and the need to produce around 300,000 similar vehicles to achieve economies of scale, the investment needed to enter the domestic auto market is $779 million of which $724 million would be needed to provide annual style change capability.

An example of this problem is developing right now where Malcolm Bricklin, an entrepreneur from Arizona is trying to start a company in Nova Scotia. He is avoiding the annual style change by producing one model which he hopes to keep the same for a number of years. He has been able to fund his company and design an automobile and get into production for approximately the difference between the $779 million and the $724 million.

Recent plant conversions for the production of smaller cars have been accomplished at a cost of between $50 and $100 million each with the current orgy of such conversions estimated to cost between $4 and $6 billion.

Yet this industry claims to spend money only on the order of millions and tens of millions of dollars each year for fundamental research and development work into new safety, emission control, and new powerplant technology. Much of this work, such as on the Wankel engine, stratified charge engine, turbines, and Stirling engine is based on old or borrowed technology, sometimes paid for at a cost in excess of the probable cost of original research and development work.

It is interesting that General Motors has paid $50 million for the right to develop the Wankel engine and use it in production cars. This is approximately twice the total that is being authorized in H.R. 10392.

The industry's inflated quotations on the amounts spent on emission controls and safety account for money spent on specific applications and emissions and safety certification work, almost none of which advances the technology significantly. The lion's share of this development work is aimed at improving fuel economy, drivability, comfort, and reduced costs consistent with minimally meeting the Federal standards mostly using the technology of the 1930's. For example, General Motors projected expenditures of $350.7 million on emission control research and development for 1973. Yet GM's claimed expenditures for alternative engine systems is less than 10 percent of this total. Ford Motor Co. followed in lock step, spending less than 8 percent on alternative engines out of a budget of $340.1 million in 1973. Chrysler Corp. brought up the rear with total emission control expenditures of $46.5 million in 1973 of which $3.9 million went to alternative engine research.

In the emission control area, the Justice Department disclosed in 1969 the real reason for the domestic auto industry's delay in cleaning up exhaust and other emissions. The Department filed an antitrust suit against the domestic car makers and their trade association, the Automobile Manufacturers' Association now known as the Motor Vehicle Manufacturers' Association), for conspiring to restrain the development and marketing of auto exhaust control systems since 1953.

The evidence brought together prior to this suit by a Los Angeles grand jury outlined the cross-licensing agreement and other close associations between these so-called auto competitors that forged this illegal, united front of inaction. The grand jury wanted to indict the companies but the top antitrust division officials overruled their own trial attorney and filed a civil suit instead in January 1969. In September 1969, the domestic auto makers entered into a consent agreement with the Government, agreeing never again to engage in such a conspiracy.

According to an Environmental Protection Agency memorandum, the automotive air pollution resulting from this conspiracy cost the American Government $2.7 billion. The cost to the American public was even higher. The continuing absence of more efficient and cleaner alternatives to the traditional piston type internal combustion engine causes the damages to mount even to this day. According to the Department of Justice, the domestic auto manufacturers rejected the cheaper, more fuel economy, and lower emission stratified charge engine at least 15 years ago:

> The quote here is from a Justice Department memorandum: "For instance, in the late 1950's Ralph Heinz, inventor, developed and patented a stratified charge engine which reduced hydrocarbon, carbon monoxide, and oxides of nitrogen emissions, while at the same time effecting a savings in gasoline consumption. Moreover, the stratified charge engine would replace the conventional engine with little or no additional cost to the consumer. The development of this engine was publicized generally so that the automobile manufacturers knew of its existence and what it would do. In fact, Victor G. Raviole, former executive director of the Ford engineering staff, stated on several occasions in the early 1960's that the major automobile companies were investigating such an engine and on one occasion predicted that it might be ready for production before 1965. However, the automobile manufacturers have evidenced little faith in this approach and no such engine has been produced by any of them."

I think that quote is probably still true today.

If the domestic auto industry had converted to the stratified charge engine, the consumer would have saved $120.60 for the emission controls on 1974 cars according to the National Academy of Sciences and at the same time would have enjoyed 12 percent better fuel economy according to the EPA.

This fall, the stratified charge engine with its various consumer and environmental benefits will appear on the American market. The only catch is that the engine had to go to Japan before coming home to America. It is Honda, a small Japanese company, that has spent $50 million for research and development on the stratified charge engine. In addition, Honda has spent $20 million to convert its existing engine line to build stratified charge engines and $80 million to add another stratified charge engine production line.

A specific example of the relaxed approach to new engine development can be found in Chrysler's turbine work. Chrysler claims that it first began to work on turbine powerplants for automotive applications in 1946. That was shortly after turbine began to be used in jet aircraft. Their first working model was constructed in 1954, and in 1963, Chrysler was sufficiently confident of its success that it built, and loaned to various members of the public, 50 turbine-powered cars. By its own count, Chrysler has produced six generations of turbines. However, it has required a $6.4 million grant from the Environmental Protection Agency to stimulate further development work. It seems incongrous that the Federal Government should have to subsidize research and development work that will probably be in the self-interest of this multibillion-dollar corporation. By comparison, GM and Ford participated in the Department of Transportation's experimental safety vehicle program on $1 contract basis.

Nevertheless, there may be a place for direct Federal stimulus to the development of alternative power systems for land vehicles. Small research and development companies such as Steam Power Systems, about which you heard on February 6, 1974, and entrepreneurs like William Lear and the Carter family from whom you will hear on June 18, without the historical encumbrances of the auto makers and of traditional automotive engineering, may be able to make the breakthroughs necessary to achieve the revolutionary design changes that will be necessary for the continued coexistence of man and his transportation systems.

I am skeptical, however, about the auto companies' ability to respond to this challenge without external stimulus which could cause one or more of the companies to break ranks with the bailing wire approach to safety and emission controls demonstrated by the industry during the last decade.

H.R. 10392 proposes that the National Aeronautics and Space Administration be given the authority to carry out research and development work on alternative propulsion systems. We think, however, that before this legislation is passed, serious consideration should be given to vesting that authority in either the Department of Transportation or the Environmental Protection Agency.

Each of these agencies has had considerable experience in contracting work with private firms as well as with other governmental agencies such as NASA and the National Bureau of Standards. Such authority falls more naturally in the mission of either the EPA or the DOT than with NASA. In any event, I would assume that a majority of the work carried out under the authority of this bill would be carried out under contract rather than in government facilities. The crucial question may be which agency has the most capable contract managers to make the most effective use of this funding.

The characteristics of ground propulsion systems that would be encouraged should go beyond those specified in H.R. 10392. There are five primary areas in which goals should be specified: (1) use of low-grade or easily obtainable fuels, (2) economy of production and operation (including fuel use in a variety of operating modes, lubricant and coolant use, a high power-to-weight ratio and power-to-size ratio, use of common or inexpensive construction materials, and durability and ease of repair—these materials also should be susceptible to recycling, of course), (3) low emissions as an inherent characteristic, (4) safe operating parameters, and (5) flexibility to operate in a wide range of conditions and power demands.

The use of diesel oils in powerplants has the dual advantage of requiring fuels that are less refined (which consequently produce more energy per barrel of crude oil at lower cost) and of having an inherently reduced risk of fire in a crash or other mishap. In addition, engines that use ethanol from the enzymatic hydrolysis of cellulose wastes should be encouraged in the event that the process becomes commercially feasible in the near future.

High power-to-weight and power-to-size ratios are necessary to obtain the most economical vehicles and efficient space utilization in personal transportation. The demands of flexibility in speed and power output, as well as its small size, are probably the reasons for the dominance of the piston type internal combustion engine in the past.

The problems that will confront any agency that undertakes the mission to develop a viable alternative to the internal combustion engine, the diesel bus and truck engine, and the electric motors of trains and subways, will be manifold. Consideration must be given to the variety of thermodynamic cycles: Otto, diesel, Rankine Stirling, and others. In addition, to the methods of utilizing these cycles include piston-type engines, rotary designs of various types, and turbines. Finally, the combination of an engine and the means of translating engine motion into vehicle motion can be mechanical, hydraulic, electrical, and even magnetic, and may involve energy storage devices such as flywheels, batteries, and even storage of fuels, manufactured on the vehicle for use in the engine.

It is tragic that the industry that will benefit most from the fruits of H.R. 10392 has shown so little interest in privately carrying out or funding the type of research envisioned in that bill. Perhaps the artificial competition that will be spurred by the passage of H.R. 10392 will have the additional side effect of stimulating these giants into additional complimentary research and development work.

Thank you, Mr. Chairman.

Mr. SYMINGTON. I want to thank you very much for an excellent and interesting statement.

Mr. Brown?

Mr. BROWN. Mr. Nash, you have indicated at a couple of points here that you wish to include in the record some additional material having to do with the lawsuits which were brought. Do you have that material?

Mr. DITLOW. We have a package of that material that we will send to the staff.

Mr. BROWN. May I request that it be made a part of the record?

Mr. SYMINGTON. It is so ordered.

[Additional material requested for the record follows:]

ENVIRONMENTAL PROTECTION AGENCY
Air Pollution Control Office

Date: January 22, 1971

Reply to Attn of:

Subject: Economic Effects of Health-Justice Department Revised

To: Dr. Ronald Engel, Assistant Director
Bureau of Criteria and Standards

The attached report includes revisions and suggestions by Mr. Louis Lombardo. Paragraphs 2 and 3 under Assumptions have been revised. In place of using total expenses of the Veterans Administration, total expenses for medical and administrative expenses is used in calculating the added cost resulting from health effects of automobile exhaust.

Wilson B. Riggan
Wilson B. Riggan, Ph.D.

Attachment

cc: Dr. Newill

HEALTH COSTS TO THE FEDERAL GOVERNMENT OF MOTOR VEHICLE AIR POLLUTION: ADDITIONAL COSTS TO THE VETERANS ADMINISTRATION AND FOR FEDERAL MEDICINE FACILITIES AND MANPOWER TRAINING

W. B. Riggan, C. R. Sharp, and W. C. Nelson

Supplement to an In-house Project Report

Ecological Research Branch
Division of Health Effects Research
Bureau of Criteria and Standards
Air Pollution Control Office
Environmental Protection Agency

January 1971

Health Costs to the Federal Government of Motor Vehicle Air Pollution: Additional Costs to the Veterans Administration and for Federal Medicine Facilities and Manpower Training

This is a supplement to the report, "Cost to the Federal Government of Health Effects Damage Attributed to Air Pollution From Motor Vehicles". Cost estimates in this report were omitted from the original report.

Assumptions:

For U. S. Public Health Service General Hospitals in 1969, the percentage of bed days used by discharged patients, who were diagnosed as having lung cancer, heart disease, and respiratory disease, is an estimate of the percentage of the total health cost which can be attributed to these diseases.

Number of individuals granted total disability by Social Security increased by more than 60 percent between 1957 and 1969.[1,2] Also, proportion of individuals with respiratory disease increased 16 percent during this time period.

Estimates in this paper do not include the change in the relative importance of respiratory disease. Even with this omission, present estimates are conservative and deviations or errors are under-estimates in spite of the changes in importance of respiratory disease and heart disease during the period considered. Hospital days used as

the basis for estimating the relative importance of each disease include both men and women. Medical expenses by the Veterans Administration are for men mostly. The diseases considered occur much more frequently among men than among women. Hence, the percentage of hospital days is lower than it would have been if only hospital days for men had been used.

Conversion factor:

Statistics reported and the accounting system used by the Veterans Administration and subsidies by the federal government fail to carry the specific added cost for health effects damage attributed to air pollution from motor vehicles. In fact, the data fail to list separately the cost of lung cancer, arteriosclerotic heart disease including coronary, acute and chronic bronchitis and emphysema. For this reason, it is necessary to use supplemental data and the previous assumptions to calculate a conversion factor for separating the desired cost fraction from medical and administrative expenses of the Veterans Administration, total grants, subsidies to private hospitals, training grants, fellowship and other forms of support of health facilities and training by the federal government.

Hospital discharges from Public Health General Hospitals in 1969 were used to calculate the conversion factor. The total number of patients with lung cancer (ICD 160 - 164), heart disease (ICD 420), and bronchitis, acute and chronic respiratory disease including

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emphysema (ICD 500 - 502, 525 - 527), and the average stay were used to calculate hospital days for each group and percentage of total hospital use of each group.

The previous report derived an estimate of 10 percent of lung cancer deaths, 10 percent of bronchitis and emphysema deaths and 2.5 per cent of heart disease deaths as being attributed to air pollution from motor vehicle exhaust. The percentage of total hospital usage attributed to air pollution from motor vehicles is shown in Table 1. The 3 diseases accounted for .71 percent of total hospital usage.

Added expenditures by the Veterans Administration:

Medical and administrative expenses of the Veterans Administration ranged from 1.0 billion dollars in 1960 to 1.7 billion dollars in 1969. The final value has been converted to 1970 dollars using 6 percent interest rate compounded annually (Table 2). The estimated added cost ranges from 12.6 to 13.8 million dollars per year. The estimate is that the federal government spent 158.7 million dollars more on medical expenses for veterans than they would have without air pollution from motor vehicles.

Added expenditures by the federal government for medical facilities and training:

Expenditures for subsidies for private hospital construction, health manpower education and utilization support and training fellowship

and research grants for 1960 - 1969 are given in Table 3. Using the conversion factor used for the Veterans Administration of 6 percent interest compounded annually, the added expenditures by the federal government are shown in Table 4. The total estimate is 125.2 million dollars for the 12 year period.

Summary:

Using certain necessary assumptions, a conservative estimate is made of the added cost to the Veterans Administration and the added contribution by the federal government for medical facilities and training. This estimate for Veterans Administration is 158.7 million and for the federal government is 125.2 million. The estimated total added cost to the federal government for veterans, medical facilities and training is 283.9 million for the 12 year period.

References.

1. Social Security, Disability Applicant Statistics - Annual Issues - starting 1963 and continuing to date.

2. Insured and Disability Workers and Social Security Disability Program Characteristics and Benefit Payments, 1957 - 1963, Social Security Administration, Office of Research and Statistics.

3. Part 2 - Diagnostic and Demographic Data, Federal Health Programs Service Annual Statistical Summary, Fiscal Year 1969, Superintendent of Documents, U. S. Printing Office, Washington, D.C.

4. Statistical Summary to Annual Report 1969 Administration of Veterans Affairs, Superintendent of Documents, U. S. Printing Office, Washington, D.C.

5. Subsidy and Subsidy - Effects Program of the U. S. Government. Materials prepared for the Joint Economic Committee, Congress of the U. S., U. S. Printing Office, Washington, D.C., 1965.

Table 1

Hospital Discharges, Diagnostic Groupings
Mean Stay (Days), Percentage of Total Due
to Automobile Exhaust

Cause	ICD code	Total number[a]	Mean stay days[a]	Total stay days[a]	Percentage of total in diagnostic groupings	Percentage of[b] diagnostic groupings due to auto exhaust	Percentag total hos usage du auto exh
Total	All	42,046	17.5	735,805	100		
Lung Cancer	160-164	475	40.6	19,285	2.6	10	.26
Heart[c]	420	1341	19.4	26,015	3.5	2.5	.09
Respiratory[d]	500-502 525-527	1998	26,386		3.6	10	.36
Total							.71[e]

Source: Part 2 - Diagnostic and Demographic Data, Federal Health Programs Service Annual Statistical Summary, Fiscal Year 1969, Table 2, page 10, U. S. Superintendent of Documents, U. S. Printing Office, Washington, D. C.

a. The patients discharged from Public Health Service General Hospitals by diagnostic groupings and mean stay during fiscal year 1969.

b. Percentages derived in "Cost to the Federal Government of Health Effects Damage Attributed to Air Pollution from Motor Vehicles.

c. Arteriosclerotic heart disease including coronary (ICD 420).

d. Acute and chronic bronchitis and emphysema (ICD 500-502, 525-527).

e. Conversion factor for use on total expenditures for deriving extra expenditures due to auto exhaust.

Table 2

VA Expenditures (Non-Accrual Basis)-Fiscal
Years 1958-59, 1970 Value of Added Expense Because
of Motor Vehicle Emissions
(Amount in Million Dollars)

Year	VA Medical and administrative expenditures[a]	Extra VA expenditures due to auto exhaust	1970 Value at 6% compound interest	1970 Value of extra VA expendi due to automobil exhaust
1958	940	6.67	2.01	13.4
1959	1,012	7.19	1.89	13.6
1960	1,084	7.70	1.79	13.8
1961	1,153	8.19	1.69	13.8
1962	1,196	8.49	1.59	13.5
1963	1,246	8.85	1.50	13.3
1964	1,292	9.17	1.42	13.0
1965	1,358	9.64	1.34	12.9
1966	1,406	9.98	1.26	12.6
1967	1,518	10.78	1.19	12.8
1968	1,620	11.50	1.12	12.9
1969	1,735	12.32	1.06	13.1
			Total	158.7

a. Source: Statistical summary to annual report 1969 Administrator of Veterans Affairs, Table 63, page 59. This includes hospital and domiciliary facilities (construction and related costs), grants for construction of state nursing homes, National Cancer Institute Public Health Service (transfer to Veteran Administration), grants to the Republic of the Philippines, and medical and administrative expenses.

Table 3

Federal Expenditures for Medical Facilities and Training (amount in million dollars)

Year[e]	Subsidy for private hospital construction	Health manpower education and utilization support[c]	Training fellowship and research grants[d]	Total
1958	44	127	189	360
1959	62	161	240	463
1960	80	195	293	568
1961	93	205	439	737
1962	95	224	582	901
1963	113	237	689	1,639
1964	125[a]	239	748	1,174
1965	193	360	772	1,325
1966	196	417	819	1,432
1967	205	553	911	1,669
1968	253	634	847	1,734
1969	255[b]	503	752	1,510

a. Subsidy and Subsidy-Effects Programs of the U. S. Government - Materials prepared for the Joint Economic Committee, Congress of the U. S., U.S. Printing Office, Washington, D. C., 1965. Table 2. Pp. 24 - 25. Data for 1960 - 1964 are appropriations.

b. Construction reports - Value of new construction put in place, U. S. Department of Commerce, Bureau of Census, August 1970, U. S. Printing Office, Washington, D. C., Table 5, P. 11. Data for 1965 - 1969 are value of construction put in place.

c. NIH Almanac 1965, Prepared by Office of Information, NIH, Bethesda, Maryland 20014. Bureau of Health Professions Education and Manpower Training Support Programs, Fiscal Years 1955 - 1969, Pp. 66 - 67. This includes Hill - Burton Hospital construction.

d. NIH Almanac 1965, Research Grant Appropriations, Training Program Appropriation, and Fellowship Awards Appropriations, Pp. 83, 84, 85.

e. Years 1958 - 1959 are extrapolated from data for years 1960 through 1969.

Table 4

Additional Federal Expenditures for Medical Facilities and Training Due to Motor Vehicle Emissions
(amount in million dollars)

Year[a]	Federal expenditure for medical training and facilities	.71 percent of total expenditure	1970 value at 6% compound interest	1970 value of added expenditures exhaust
1958	360	2.6	2.01	5.2
1959	463	3.3	1.89	6.2
1960	568	4.0	1.79	7.2
1961	737	5.2	1.69	8.8
1962	902	6.4	1.59	10.2
1963	1,039	7.4	1.50	11.1
1964	1,174	8.4	1.42	11.8
1965	1,325	9.4	1.34	12.6
1966	1,432	10.2	1.26	12.8
1967	1,669	11.8	1.19	14.1
1968	1,734	12.3	1.12	13.8
1969	1,510	10.7	1.06	11.4
			Total	125.2

Source: Table 3

a. Years 1958 - 1959 are extrapolated from data for years 1960 through 1969.

Table 5

VA Expenditures (Non-Accrual Basis)-Fiscal Years 1960-69, 1970 Value of Added Expense Because of Motor Vehicle Emissions
(Amount in Million Dollars)

Year	VA Medical and administrative expenditures[a]	Extra VA expenditures due to auto exhaust	1970 Value at 6% compound interest		1970 Value of extra VA expenditure due to automobile exhaust
1960	6,376	45.3	1.79		81.0
1961	6,802	48.3	1.69		81.6
1962	6,709	47.6	1.59		75.7
1963	7,004	49.7	1.50		79.1
1964	7,052	50.1	1.42		71.1
1965	7,1[illegible]9	50.7	1.34		67.9
1966	7,472	53.1	1.26		66.8
1967	8,122	57.7	1.19		68.6
1968	8,55[illegible]	60.7	1.12		68.0
1969	9,159	65.0	1.06		68.9
				Total	728.7

a. Source: Statistical summary to annual report 1969 Administrator of Veterans Affairs, Table 63, page 59. This includes hospital and domiciliary facilities (construction and related costs), grants for construction of state nursing homes, National Cancer Institute Public Health Service (transfer to Veteran Administration), grants to the Republic of the Philippines, and medical and administrative expenses.

ENVIRONMENTAL PROTECTION AGENCY

Air Pollution Control Office

Date: January 15, 1971

Reply to Attn of:

Subject: Revised Report on the Economic Cost of Air Pollution Due to the Automobile, 1953-70

To: Louis Lombardo
Office of Standards and Compliance, APCO

Please find enclosed copies of the latest revised report on the Economic Cost of Air Pollution Due to the Automobile, 1953-70.

Donald G. Gillette

Donald G. Gillette
Chief, Effects Assessment Branch
Division of Economic Effects Research

2 Enclosures

THE ECONOMIC COST OF AIR POLLUTION FROM MOTOR VEHICLES

Effects Assessment Branch
Division of Economic Effects Research
Air Pollution Control Office
January 1971

THE ECONOMIC COST OF AIR POLLUTION FROM MOTOR VEHICLES

SUMMARY OF ECONOMIC COST DUE TO AIR POLLUTION FROM MOTOR VEHICLES

Estimates of vegetative and material damage due to pollutants related to automotive emissions have been examined in this paper. The estimates for each type of cost are summarized for the period 1953 through 1970 as follows:

Type of Cost	Cost to the Federal Government (millions of dollars)		National Estimate of Total Cost (millions of dollars)	
Vegetative damage	45		1,136	
Material damage	122		6,173	
Rubber		48		3,711
Textiles		74		2,462
Governmental expenditures	41		43	
Total	208		7,352	

Thus the total estimated cost was approximately $7.4 billion, and the Federal Government's share of this cost was about $0.2 billion, or 2.8 percent of the total.

For the year 1970 the costs were estimated as follows:

Type of Cost	Federal (millions of dollars)		Total (millions of dollars)	
Vegetative damage	5		114	
Material damage	11		548	
Rubber		4		286
Textiles		7		262
Governmental expenditures	14		15	
Total	30		677	

ECONOMIC COSTS OF AIR POLLUTION FROM MOTOR VEHICLES

The automobile was spawned by the emerging technology of the early twentieth century. From a total of only 8 thousand motor vehicle registrations in 1900, by 1968 the total had reached more than 100 million,[1] with the total doubling between 1950 and 1968.

Driving a car has become an institution in this country. In a recent report[2] it was stated that, "Use of the private automobile for personal transport has been one of the distinguishing hallmarks of this Nation's culture." The same report goes on to discuss the consequences of this phenomena; "Only recently have social problems associated with their widespread use, such as air pollution, become a matter of public concern. Automotive emissions were identified as an important source of atmospheric contaminants in the early 1950's, when they were shown to be the major contributor to the chemical reactions which create atmospheric smog in the Los Angeles basins."

The pollution problem related to motor vehicles has received widespread publicity in the Los Angeles area; however, it has been reported that pollution resulting from motor vehicles affects 26 of California's 58 counties.[3] Outside of California, manifestations of photochemical smog have been observed in more than 20 states, the District of Columbia, Canada, Mexico, and parts of Europe.[4] In an attempt to roll back the concentrations to the levels existing around 1940, emission

standards for CO and HC have been imposed on a national basis. California has also set standards for NO_x and O_x.[5]

One means of reducing pollution related to automobile emissions would be to modify or change the power source. Some modifications might include a high velocity carburetor, an optimized spark timing, a recycling of exhaust gases, fuel changes, and catalytic afterburners. Perhaps a different type of engine could be employed; some well-known examples include the battery powered engine, the steam engine, the gas turbine, the Wankel (or rotary) engine, the steam engine, the gas engine.[6] Unfortunately, these latter alternatives, if feasible, are several years in the future.

Since controls currently are required only on new cars and approximately 4.5% of the vehicles miles traveled are by vehicles 12 years of age and older,[7] the problem of emissions from motor vehicles will be present for years, barring a major technological breakthrough. In view of this situation it is pertinent for APCO to identify and estimate the extent of damage caused by pollutants related to vehicle emissions. This paper will provide economic estimates of damages to vegetation and materials incurred by the public and private sectors of our economy.

I. The Effects of Air Pollution from Motor Vehicles on Vegetation

A. Horticultural and field crops

Photochemical or oxidant air pollution damage to crops was first noticed in Los Angeles County in 1944. In 1949 damage to eleven se-

lected leafy and vegetable crops in that county caused an estimated loss of approximately $480,000.[8] By 1950 crop damage was reported in the neighboring counties of Orange, Riverside, and San Bernardino as well as from the San Francisco Bay Area.[9] By 1956 economic damage to crops was reported in 19 counties in the state of California;[10] 27 counties were involved by 1961.[11]

In 1967, smog damage in Los Angeles County alone was estimated to have caused a minimum of $4,000,000 in crop losses.[12] These losses were based mainly on reports of actual field damage reported by farmers or that damage noted by field inspections. This figure does not take into account losses to ornamentals that have been incurred by homeowners and the like. Thus, we can conclude that this estimate is quite conservative and indeed, the actual figure of plant losses sustained in Los Angeles County is probably several times higher.

Crop losses due to the effects of photochemical air pollutants are also being realized throughout the agriculturally rich San Joaquin and Sacramento Valleys.

The California Department of Public Health estimated that annual losses of agronomic species due to air pollution in California could total $100,000,000.[13] Van Brackle stated in 1967 that in California alone when one considers more than visible affects, annual smog damage to agricultural crops may be as high as $132,000,000.[14]

Photochemical air pollution damage to plants is not unique to California by any means. Damage symptoms of ozone have been reported in at least 20 states and the District of Columbia.[15] The same

report cites the growing importance of photochemical air pollution along the Eastern Seaboard of the United States. In 1961 crop losses along the Seaboard were conservatively estimated at $18,000,000.[16]

In 1968 an estimated $3,000,000 loss to the cigar wrapper tobacco industry in the Connecticut River Valley was attributed to oxidant air pollution.[17] In the densely populated state of New Jersey, one field investigator has reported ozone injury on 17 different crops growing in that area. Ozone has seriously jeopardized the continued commercial production of spinach, and possibly endive, chicory, and some varieties of petunias in New Jersey, and there is evidence that some growers of spinach in the Philadelphia area have been forced out of production because of increasing oxidant levels.[18] To what extent automobiles contribute to the air pollution problem in this eastern section of the country is not known, but it is believed that they are the major contributor of the raw material for photochemical air pollutants.

The floricultural industry in many large urban areas has historically been affected by the photochemical pollution complex. Years ago orchid growers were forced out of production in the Los Angeles Area. Near San Francisco the combined loss to three orchid growers amounted to about $70,000 in one year alone.[19] These losses were attributed to ethylene, a product of the automobile exhaust.

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B. Damage to Forests

In 1969 an estimated 1.3 million ponderosa pines, which were located on approximately 100,000 acres of the San Bernardino National Forest lands, were adversely affected and exhibited smog type injury from the generation of photochemical pollutants arising out of the Los Angeles Basin.[20] Because of its proximity to Los Angeles and its scenic beauty, the San Bernardino Forest attracts millions of people annually to partake of its many recreational opportunities. Land in the resort area adjacent to Lake Arrowhead has been valued from $50,000 to $60,000 per acre.[21] This land valuation is closely tied to the presence of ponderosa pine, for similar plots without such trees are valued at less than $20,000 per acre.[22] To put an economic valuation on recreational use, aesthetic beauty, and watershed protection, is most difficult, but nevertheless the loss is quite significant. Of even more importance is the potential area that might be affected. In addition to the San Bernardino National Forest, forest stands are being affected by smog in the Santa Cruz area and in the vicinity of Sequoia National Forest.[23]

C. Summary of Vegetative Costs

As noted earlier, the first losses due to vegetative damage from automobile related pollutants were reported in 1949. To estimate the total vegetative damage since 1949, it was assumed that the increased

damage was directly proportional to the increase in motor vehicle registrations. The estimates of vegetative damage attributed to this source of pollution for the years 1953 through 1970 inclusive, are shown in Figure 1. For this period the emissions from the automobile were estimated to be responsible for $1.1 billion for plant and crop damage in this country. (See Table 3)

The two major ingredients of the photochemical smog are NO_x and ozone. On the average across the nation 38% of the NO_x emitted into the atmosphere can be associated with the automobile. This figure reflects a high, in six west coast SMSA's, of nearly 57% of the total oxides of nitrogen and a low of only 18% of the total oxides of nitrogen in east coast SMSA's. However, the persistent increase in pollution levels and the resulting damages must be attributed to the automobile.

It should be recognized that the year to year variation in the amount of damage caused by air pollution may be considerable. In 1967, for example, some estimates of damage reported in California alone exceeded the estimated level shown in Figure 1.[24] Most of the estimates on vegetative damage are inadequate for deriving national estimates because of the lack of systematic methods of assessing damages and the limited area and number of crops for which said assessments were made. Consequently, in arriving at the national damage levels, extrapolations of probable damage to other crops and production areas were necessitated.

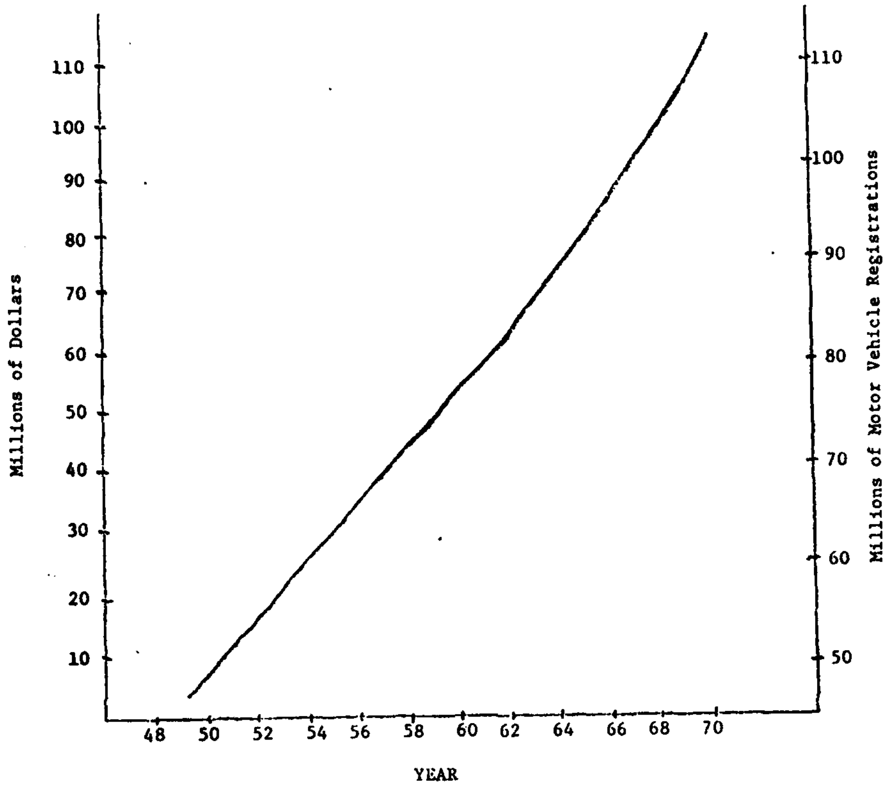

Figure 1. ESTIMATED TOTAL VEGETATIVE DAMAGE*

* Data presented in Table 3.

II. Material Damage Due to Air Pollution from Motor Vehicles

A. Damage to Rubber Materials

1. Cost of Additives

The most common preventive measure employed to reduce damage due to automobile emission pollution is the addition of an antiozonant to rubber. Preliminary results from a recent progress report of a contracted study indicate that the cost of adding antiozonants is approximately one percent of the total market value of tires sold.[25] The total rubber market for 1968 was $8 billion,[26] and tires accounted for $5.2 billion or 65 percent of the total.[27] Thus, the cost of adding antiozonant to tires in 1968 amounted to $52 million. Not all of this cost, however, can be attributed to the pollutants emitted by the automobile. Since ozone occurs naturally in the atmosphere, there would even be ozone concentrations without internal combustion engines. This background concentration at sea level has been estimated as about .02 to .04 ppm.[28] Consequently, the total antiozonant costs for tires were discounted by 20 percent to reflect a more realistic estimate of those costs that can be attributed to auto emissions. In 1968 this cost was estimated to be around $42 million. With 1968 as the base year and assuming the cost per tire of the additive remained constant for the period of interest, the annual cost was estimated as follows based on the number of tires shipped.[29]

$$\frac{\text{Cost (x year)}}{\text{Cost - 1968}} = \frac{\text{Number of Tires Shipped (x year)}}{\text{Number of Tires Shipped - 1968}}$$

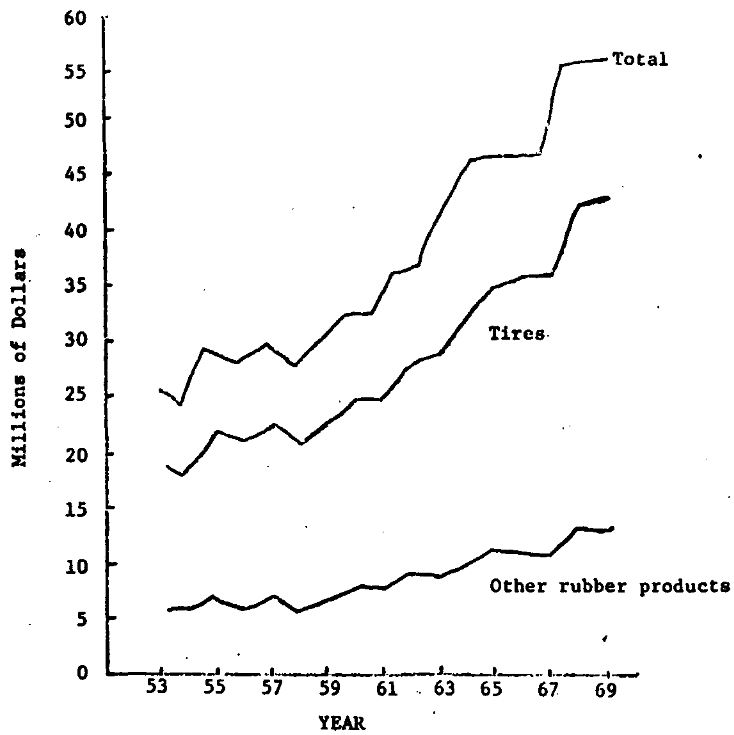

Figure 2. THE COST OF ANTIOZONANT ADDED TO RUBBER MATERIALS TO RETARD DAMAGES ATTRIBUTABLE TO VEHICLE EMISSIONS*

*Data presented in Table 3.

From 1953 to 1970 inclusive, the estimated costs attributed to the automobile was $523 million.

As stated above, approximatley 65 percent of the nation's rubber production goes into tires. Twenty percent of the total production does not go into tires, but is also treated with antiozonant. Assuming the cost of adding antiozonants to these rubber products is one percent of the total market value and the ratio of the production of rubber products treated with antiozonants to tire production remains the same, the total cost of the antiozonant for this type of rubber was estimated to be $163 million for the 18 year period.

Figure 2 shows the cost of antiozonant added to rubber materials to retard damages attributable to vehicle emissions from 1953 to 1970. The data including the annualized costs can be found in Table 3.

2. Premature Failures and Replacements Costs

The second element to be considered in estimating the cost of pollution damage to rubber goods is the cost of replacement. Obtaining information on the types and numbers of failures of rubber products and even more important the causes of these failures is understandably a difficult problem.[30] For the major subgroup tires, a recently completed research contract yielded an estimate of replacement cost for the year 1970 of $37 million.[31] The assumptions made were that not over 3 percent of tire replacement is caused by sidewall failure and that these tires have been driven an average of 75 percent of their normal life.[32] The cost of replacement for tires was estimated as $496 million for the period 1953 through 1970 as follows:

$$\frac{\text{Cost (x year)}}{\text{Cost (1970)}} = \frac{\text{Motor Vehicle Registration (x year)}}{\text{Motor Vehicle Registration (1970)}}$$

Mechanical goods, wire and cable, hoses, and miscellaneous goods comprise the category, other rubber products. An estimate of replacement costs for this group for the year 1970 is $189 million at the retail level.[33] The estimate does not include the labor cost of replacement since a realistic estimate cannot be made. With 1970 as the base year, the annualized cost for the period of interest was estimated as follows:

$$\frac{\text{Cost (x year)}}{\text{Cost (1970)}} = \frac{\text{Motor Vehicle Registration (x year)}}{\text{Motor Vehicle Registration (1970)}}$$

The estimated total cost from 1953 through 1970 was $2.5 billion.

An additional area in estimating the cost of pollution damage to rubber goods relates to the replacement of costly assemblies when a rubber component fails. It is extremely difficult to estimate this type of damage because it is frequently not known which component caused the failure. A few estimates for certain types of industry have been attempted. A wire and cable industry spokesman estimated that if labor costs are included, the cost to that single industry might be as high as $24 million annually.[34] The automotive industry also has a replacement problem other than tires, but no figures are available, to date there is no estimate of the total cost for entire subassemblies, but indications are that the costs will be substantial.

SUMMARY OF COSTS FOR OZONE DAMAGE TO RUBBER
ATTRIBUTED TO AUTOMOBILE EMISSIONS 1953-70

	Millions of dollars
Antiozonant (tires)	523
Antiozonant (non-tires)	163
Premature failure (tires)	496
Premature failure (other products)	2529
	3711

B. Damage to Textiles

1. Deterioration of textiles

The damage to fabrics due to air pollution resulting from motor vehicle emissions is difficult to assess. An attempt to estimate textile damages (fading excluded) due to gaseous pollution was made by Salmon of the Midwest Research Institute.[35] To obtain the values presented in Table I, Salmon used the product of annual dollar volume, economic life, and a labor content factor to provide a measure of the total value of a material in use. Multiplying this total value by the fraction of the material actually exposed to air pollution provided a value of in-place material exposed to air pollution.

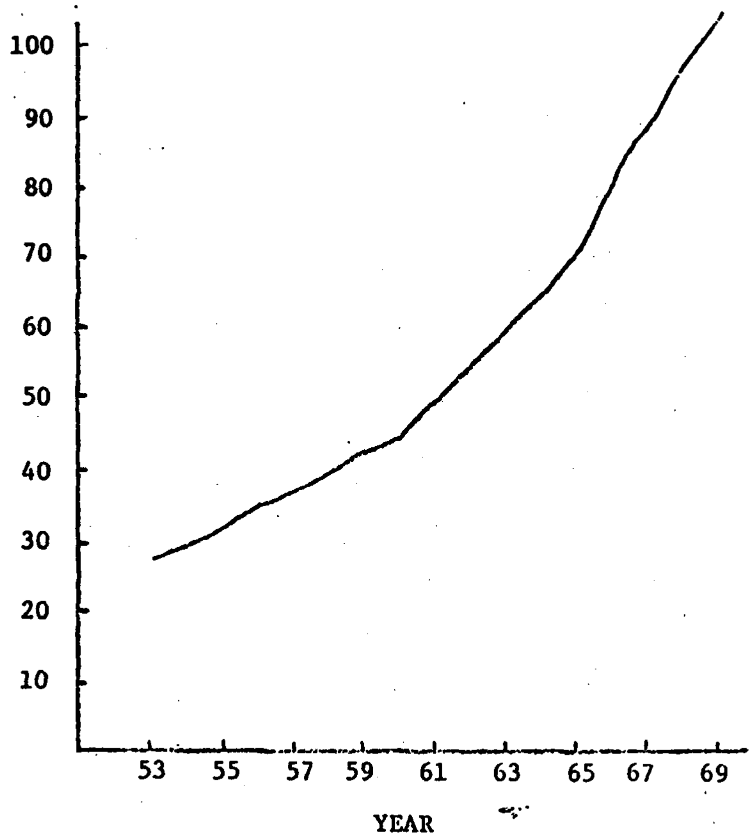

Figure 3. ECONOMIC LOSS* TO TEXTILES DUE TO AIR POLLUTION FROM MOTOR VEHICLE EMISSIONS**

*Fading of dyes excluded.

**Data presented in Table 3.

TABLE I

DETERIORATION DUE TO GASEOUS POLLUTION

Fabric	Annual Production (Billions)	Economic Life	Value of In-place Material Exposed to Air Pollution (Billions)	Economic Loss to Textiles (Millions of Dollars)
Cotton	3.34	6	3.80	152.0
Wool	1.08	6	2.48	99.2
Nylon	.83	6	.95	38.0
Cellulose ester	.22	6	.82	32.8
Rayon	.29	6	.33	15.2
Acrylics	.17	6	.19	7.6
Acetate	.16	6	.19	7.6
Polyester	.14	6	.16	6.4
Polyolefins	.04	6	.04	1.6
Total	6.27		8.96	360.4

If one assumes that one-third of this damage may be attributed to O_3 and perhaps NO_x from automobiles,[36] then the estimate of annual damages to textiles would be approximately $120 million. Correcting for an O_3 background of 20%, the estimate for 1968 becomes $96 million. Using the national income of the textile industries from apparel and fabricated textile products for the past 18 years and assuming the damage is proportional to the number of vehicles in use, the annual costs were estimated using 1968 as the base year,

$$\frac{\text{Cost (x year)}}{\text{Cost - 1968}} = \frac{\text{National Income (x year)}}{\text{National Income - 1968}} \times \frac{\text{Motor Vehicle Registrations (x year)}}{\text{Motor Vehicle Registrations - 1968}}$$

The total costs for the period of interest was about $1.1 billion.

2. Fading of dyes

Preliminary estimates of the economic cost of the fading of dyes on textiles due to NO_x and O_3 have been obtained from a contract now in progress.[37] The numbers must be qualified insofar as the final figures will be based upon more complete production data and remedial processing costs. However, the contractor believes that the relative magnitude of the estimates will remain unchanged. The damages from NO_x have been modified to account for the fact that only about 50% of the NO_x emitted into the atmosphere comes from motor vehicles.[38] The assumption that 20 percent of the O_3 concentration may be attributed to background was retained for this section.

The economic cost of NO_x fading of acetate dyed fabrics was broken down into several categories. These include increased cost of dyes more resistant to NO_x fading; cost of inhibitors for cheaper dyes; cost of research; cost of quality control related to use of more expensive dyes; loss due to fading at the manufacturer or retail levels and cost to consumers in the form of reduction in wear-life. The annual total cost of NO_x damage to acetate dyed fabrics was estimated to be $36 million.

The economic cost of NO_x fading of dyes on viscose rayon was estimated by assuming a two year wear-life and a premature loss in wear-life of 10 percent. The annual estimated cost totaled $11 million.

The economic cost of NO_x fading of cotton dyes was estimated for three types of dyes. The annual damage attributable to NO_x from motor vehicles was estimated to be $3 million for sulfur dyes, $7.5 million for direct dyes and $1 million for reactive dyes, for a total cost of $11.5 million.

One further estimate of NO_x damage was the cost of optical brightners. These brightners are employed to retard yellowing of whites for acetates, spandex and nylons. The total cost in this area was about $2.8 million annually.

The ozone fading of polyester-cotton on permanent press fabrics was also investigated. The annual cost of research, quality control and testing, use of remedial dyes and finishes, extra cost of higher operating temperatures, and fading on manufacturers and retail shelves was estimated as $13.6 million. The cost of ozone fading of acetate and triacetate fabrics was also estimated, and the ozone related damage, excluding background, was calculated as about $20 million.

One other sector of the textile industry investigated was the economic cost of ozone fading on nylon carpets. The total cost to that industry of ozone related damages and research was estimated at approximately $33 million.

A summary of the estimated costs follows for the year 1968:

	Millions of dollars
NO_x fading of acetate and triacetate	36
NO_x fading of dyes on viscose rayon	11
NO_x fading of cotton	11.5
NO_x yellowing of whites on acetate-nylon-spandex	2.8
O_3 color fading of dyes on acetate and triacetate	13.6
O_3 color fading on permanent press garments	20
O_3 color fading on nylon carpets	33
Total	127.9

The overall estimate of damage for the 18-year period was determined as follows using the rate of change of the national income of the textile industry and assuming the level of damage to be directly proportional to the number of motor vehicles:

$$\frac{\text{Damage (x year)}}{\text{Damage - 1968}} = \frac{\text{National Income Textiles (x year)}}{\text{National Income Textile - 1968}} \times \frac{\text{Motor Vehicle Registrations (x year)}}{\text{Motor Vehicle Registrations - 1968}}$$

The annual costs are indicated in Figure 5 and Table 3. The estimated cost for the 18-year period was about $1.4 billion.

III. Governmental Expenditures Related to Air Pollution from Motor Vehicles

Since 1956, the Federal Government has designated a considerable sum of money for research related to emissions from motor vehicles. An effort has been made to estimate the expenditures for research grants,

survey and demonstration grants, control agency funds, and direct operations.

The annualized data for the expenditures denoted above have been tabulated in Table 2. The expenditures of the Federal Government were estimated to total $41.3 million and the state and local funds were estimated as approximately $1.7 million for the period of reference.

IV. Cost to the Federal Government of Damage Attributed to Air Pollutants from Motor Vehicles

A. Vegetative Damage

The costs to the Federal sector are estimated to be minimal relative to the total economic impact of plant losses. The smog damage to more than 100,000 acres in the San Bernardino and Angeles National Forests in southern California represents the major cost to the Federal Government. As stated earlier, some 1.3 million trees are affected to some extent by the photochemical air pollution emanating from the Los Angeles megalopolis.

Economic costs would include a reduction in tree growth and thus a loss in timber value, some loss in watershed protection, a decrease in aesthetic quality and perhaps recreational use of the forests, and a potential impact on the wildlife habitat associated with forest cover. Considering the evidence of air pollution damage that has been presented it can be estimated that the annualized costs in 1969 may total $5,000,000, and may be as much as $40,000,000 for the period of interest.

B. Material damage

The total cost of antiozonant which is added to rubber to retard cracking may be broken down into public and private costs. The cost to the Federal Government was estimated by employing production figures for defense-oriented industries and data obtained from the Annual Motor Vehicle Report.[39] Based upon this data, it was estimated that three percent of the antiozonant cost, or about $21 million, could be attributed to the Federal Government for the period in reference.

It should be noted that the assumption was made that even though the Federal Government purchases its tires at a cheaper rate, the cost of the antiozonant was the same.

The Federal Government's share of the cost of tire replacement was determined by taking the proportion of the federal fleet, approximately 0.5% of all the motor vehicles,[40] times the total cost of tire replacement due to ozone damage. This leads to an estimate of approximately $2.5 million for the 18-year period.

The Federal Government's portion of the cost of replacing other rubber products such as mechanical goods, hoses, wire and cable, and miscellaneous goods was estimated by assuming that the government installations use one percent of these goods. The estimated cost to the Federal Government was then calculated to be about $25 million from 1953 to 1970.

The Federal Government's share of the economic loss to textiles due to air pollution from motor vehicles was estimated by assuming

that 3% of this market was purchased by the Federal Government. The total damage to textiles was estimated as $2,462 million and the federal share was estimated to be about $74 million.

A summary of the damage costs to the Federal Government for the years 1953 through 1970 as follows:

	Millions of dollars
Vegetation	45.0
Antiozonant	20.6
Premature tire failure	2.5
Premature failure (other rubber goods)	25.3
Textiles	73.9
Total	167.3

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TABLE 2

FEDERAL, STATE AND LOCAL EXPENDITURES RELATED TO MOTOR VEHICLE AIR POLLUTION - ESTIMATED

Fiscal Year	Federal Research Grants	Survey & Demonstration Grants		Control Agency* Funds		Bureau of Criteria & Standards	Federal Direct Operations	Totals	
		State & Local	Federal	State & Local	Federal	Contract & Intramural	DMVPC & DMVRD Contract & Intramural	State & Local	Federal
1955									
1956	107,000								107,000
1957	430,000								430,000
1958	311,000								311,000
1959	416,000								416,000
1960	662,000								662,000
1961	596,000								596,000
1962	778,000								778,000
1963	400,000								400,000
1964	298,000								298,000
1965	349,000	41,000	124,000					41,000	473,0
1966	581,000	104,000	311,000			1,998,000	470,000	104,000	3,360,000
1967	143,000	97,000	291,000			1,535,000	1,146,000	97,000	3,115,000
1968	330,000	165,000	495,000	194,000	78,173	2,869,000	2,120,000	359,000	5,892,173
1969	525,000	100,000	300,000	315,332	120,000	4,189,000	5,665,000	415,332	10,799,000
1970	591,000	250,000	250,000	426,991	155,253	4,654,000	8,041,000	676,991	13,691,253
Totals	6,517,000	757,000	1,771,000	936,323	353,426	15,245,000	17,442,000	1,693,323	41,328,426

*The State and Local figures for this column refer only to the California State Air Resources Board. Funds utilized for motor vehicle related activities were minimal for other states.

TABLE 3

NATIONAL DAMAGE ESTIMATES ATTRIBUTED TO AUTOMOBILE EMISSIONS

Year	Vegetative Damage ($\$10^6$)	Antiozonant		Replacement Costs		Damage to Textiles ($\$10^6$)	Cost of Dyed Fabrics ($\$10^6$)	Totals ($10
		Tires ($\$10^6$)	Other ($\$10^6$)	Tires ($\$10^6$)	Other ($\$10^6$)			
	Total	Total	Total	Total	Total	Total	Total	
1953	21	19	6	19	98	27	35	225
1954	26	18	6	20	104	29	38	241
1955	29	22	7	22	112	31	42	265
1956	34	21	6	23	115	34	45	278
1957	39	23	7	23	119	36	48	295
1958	44	21	6	24	121	39	51	306
1959	49	23	7	25	127	42	54	327
1960	53	25	8	26	130	44	57	343
1961	59	25	8	26	134	49	65	366
1962	63	28	9	27	138	54	72	391
1963	69	29	9	28	144	59	79	4
1964	73	32	10	30	152	64	87	448
1965	80	35	11	31	157	70	94	475
1966	85	36	11	32	164	79	105	512
1967	92	36	11	33	168	88	116	544
1968	100	42	13	34	176	96	128	583
1969	106	43	13	36	181	104	139	622
1970	114	45	15	37	189	112	150	662
Totals	1136	523	163	496	2529	1057	1405	7309

TABLE 4

FEDERAL DAMAGE ESTIMATES ATTRIBUTED TO AUTOMOBILE EMISSIONS

Year	Vegetative Damage ($\$10^6$)	Antiozonant Tires ($\$10^6$)	Antiozonant Other ($\$10^6$)	Replacement Costs Tires ($\$10^6$)	Replacement Costs Other ($\$10^6$)	Damage to Textiles ($\$10^6$)	Cost of Dyed Fabrics ($\$10^6$)	Totals ($\$10^6$)
1953	.83	.57	.18	.10	.98	.81	1.05	4.52
1954	1.03	.54	.18	.10	1.04	.87	1.14	4.90
1955	1.15	.66	.21	.11	1.12	.93	1.26	[illegible]
1956	1.35	.63	.18	.12	1.15	1.02	1.35	[illegible]
1957	1.55	.68	.21	.12	1.19	1.08	1.44	6.27
1958	1.74	.63	.18	.12	1.21	1.17	1.53	6.58
1959	1.94	.68	.21	.13	1.27	1.26	1.62	7.11
1960	2.10	.75	.24	.13	1.30	1.32	1.71	7.55
1961	2.34	.75	.24	.13	1.34	1.47	1.95	[illegible]
1962	2.50	.84	.27	.14	1.38	1.62	2.16	8.91
1963	2.73	.87	.27	.14	1.44	1.77	2.37	9.39
1964	2.89	.96	.30	.15	1.52	1.92	2.61	10.35
1965	3.17	1.05	.33	.16	1.57	2.10	2.82	[illegible]
1966	3.37	[illegible]	.33	.16	1.64	2.37	3.15	[illegible]
1967	3.64	1.08	.33	.17	1.68	2.64	3.43	13.02
1968	3.96	1.26	.39	.17	1.76	2.88	3.84	14.26
1969	4.20	1.29	.39	.18	1.81	3.12	4.17	15.16
1970	4.52	1.35	.45	.19	1.89	3.36	4.50	16.26
Totals	45.01	15.67	4.89	2.52	25.29	31.71	42.15	167.24

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
ENVIRONMENTAL HEALTH SERVICE
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION

Date: October 9, 1970

Reply to Attn of: Assistant Chief, Ecological Research Branch

Subject: Cost to the Federal Government of Health Effects Damage Attributed to Air Pollution from Motor Vehicles.

To: Dr. Engel, Assistant Director, Bureau of Criteria and Standards REE
Through: Director, DHER
Through: Chief, ERB

1. Last week Louis Lombardo asked about clearance of the attached report. Draft copies were distributed to DHER, DEER, BCS and Louis Lombardo. I have received no suggestions for revision. I have added an abstract, introduction, and modified the summary.

2. This is a Minimum Creditable Estimate. The summary lists some of the omitted costs to the Federal Government.

Wilson B. Riggan

Wilson B. Riggan, Ph.D.

Cost to the Federal Government of Health Effects Damage Attributed to Air Pollution from Motor Vehicles[1]

W. B. Riggan, Ray Sharp, R. W. Buechley, W. C. Nelson, and V. A. Newill

Of the components considered in a cost benefit analysis of air pollution control, the health component is the most difficult to assess. This report is the first halting step to quantify health costs from a major pollutant source - motor vehicles. The report considers only direct costs to the Federal Government.

Some of the covariates which confound the results of health studies of air pollution are: Smoking history, occupational exposure, population age structure, population mobility and residential exposure.

The major pollutants emitted by motor vehicles are: (1) hydrocarbons; (2) carbon monoxide; (3) oxides of nitrogen; and (4) lead and its compounds contained in emitted particulates. Automobile exhaust is the major source of pollutants which react photochemically to form oxidants.

The percentage of deaths attributed to motor vehicle pollution are based on the results of epidemiological studies. Deaths from lung cancer, bronchitis, arteriosclerotic heart disease including coronary disease, and motor vehicle accidents are used in estimating the cost. Had these people lived a normal life, they would have paid income taxes like normal individuals from the same age cohort. Present values are needed of all income taxes which would have been paid. First, 1960 life tables were modified by adjusting the probability of death

for each of the above causes of death. New life tables were calculated for 5 year age intervals and for both sexes. Compound interest at 6 percent was added to income taxes which would have been paid before 1970 and future income tax payments which would have been made after 1970 were discounted at 6 percent.

Results of epidemiological studies were used to derive the percentage of disabled workers with bronchitis and heart disease attributed to motor vehicle pollution. These percentages were applied to social security payments for the years 1958-196. Compound interest at 6 percent was added to annual payments to arrive at the present value, January, 1970. Future payments for those who had not reached 65 by January, 1970 have not been included.

Information is not available on reduction in production resulting from eye irritation by oxidants. Estimates of the cost from lost production of government employees is calculated using the measured oxidant level at the continuous air monitoring station in Washington, D.C. This is based on an assumed 10 percent reduc work output.

The dollar costs to the U. S. Government attributable to these components were:

Mortality	$\$1.9 \times 10^9$
Disablement	$.2 \times 10^9$
Lost Production	$.1 \times 10^9$
Total	$\$2.2 \times 10^9$

Thus, somewhat over two billion dollars has been lost from Federal revenues, or expended, as the result of motor vehicle based air pollution. Are the benefits worth this cost?

This is not the complete answer. It is our first attempt and one which we present with misgivings. Our misgivings come from the inability of health studies to assess the relative contribution of relevant covariates.

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[1]Ecological Research Branch, Division of Health Effects Research, Bureau of Criteria and Standards, National Air Pollution Control Administration, Environmental Health Service, Public Health Service, Department of Health Education and Welfare, 211 West Chapel Hill Street, Durham, North Carolina 27701

Cost to the Federal Government of Health Effects Damage Attributed to Air Pollution from Motor Vehicles.

OUTLINE Wilson Riggle

Summary

I. Emissions - Health Effects

  A. Hydrocarbons - Health Effects

  B. Carbon Monoxide - Health Effects

  C. Oxidants - Photochemical Smog - Health Effects

  D. Oxides of Nitrogen - Health Effects

  E. Lead - Health Effects and body burden

  F. Minor emitted pollutants - Health Effects

II. Cost to the Federal Government

  A. Method of calculating loss of income tax collection because of premature death.

  B. Lung cancer - loss of income tax because of premature death ICD 160-164

  C. Bronchitis - loss of income tax because of premature death ICD 500-502, 525-527

  D. Arteriosclerotic heart disease, including coronary disease - loss of income tax because of premature death, ICD-420

  E. Motor Vehicle Accidents - loss of income tax because of premature death, ICD E810-E835

F. Disability payments by Social Security to workers who have not reached 65 years of age.

1. Method of calculations

2. Social Security payments to workers disabled - because of motor vehicle pollution

   a. Bronchitis ICD 500-502, 525-527

   b. Arteriosclerotic heart disease including coronary disease

3. Estimate of loss of productivity of federal employees, SMSA, Washington, D. C.

4. Other sources of loss which have not been included.

Summary:

Estimates of cost to the federal government of health effects damage related to motor vehicle emitted pollutants are examined in this paper. Present value, January, 1970 of Federal Income Tax which would have been paid "after death" by the people who died prematurely from automotive pollution in 1953-1961 and 1962-1969, had they lived normal lives is shown in Table 1. This total is $1.9 billion.

Present value, January, 1970 of social security payments to disabled workers from automotive pollution in 1958-61 and 1962-69 is shown in Table 2. These are disabled workers who have not reached 65 years of age. This total is $189.4 million. This is an underestimate since it does not include payment to widows and dependents, disability payments after December 1969, lump sum payments for premature death, or loss of income tax payments.

Deaths in Table 1 and disabled workers from automobile pollution are based on health studies. These are cited in discussion and justification for use of each value. Estimate of present value of lost production by federal government workers in Washington, D. C., SMSA for 1960-61 and 1962-69 is shown in Table 1. The number of hours of eye irritation is based on measured oxidant levels at CAMP stations in Washington, D. C. The payrolls are the actual payrolls in the area. The reduction in work is an estimate. There are no study results on the reduction in productivity. The figure of 10 percent reduction in productivity seems reasonable. The estimated loss value is $97.1 million.

Table 1.

Value in January, 1970 of Federal Income Tax which would have been paid "after death" by the people indicated below who died in 1953-1961 and 1962-1969, had they lived normal lives.

Deaths resurrected	Present value of taxes which would have been paid (Millions of dollars) 1953-1961	1962-1969	Total
10% of lung cancer deaths (ICD 160-164)	128.6	141.6	270.2
10% of bronchitis deaths (ICD 500-502, 525-527)	57.6	67.9	125.5
2.5% of heart disease deaths (ICD 420)	227.5	199.4	426.9
10% of motor vehicle deaths (E810-835)	544.4	541.6	1,086.0
Total	958.1	950.5	1,908.6

Table 2.

Value in January, 1970 of Social Security payment to disabled workers with emphysema and arteriosclerotic heart disease including coronary for the period of 1958-1961 and 1962-1969.[a]

Category of Disabled workers	Present value of payments which would not have been made. (Thousand Dollars) 1958-1961	1962-1969	Total
10 percent of emphysema (ICD 500-502, 525-527)	21,654	93,136	114,790
2.5% of arteriosclerotic heart including coronary (ICD 420)	14,916	59,692	74,608
TOTAL	36,570	152,828	189,398

a. This table includes payments through 1969. Disability payments are not included for 1970 and after for disabled workers receiving disability payments in 1969 but who have not reached 65.

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Table 3 summarizes the costs shown in Table 1 and 2. The total dollar cost attributed to motor vehicle pollution is $2.2 billion. This is a gross underestimate because of many omissions. Some of the omitted costs to the Federal Government of health effects damage are:

1. Added treatment cost of veterans;
2. Added contribution to medical facilities and training by the Federal Government;
3. Added cost of health research by the Federal Government;
4. Added cost of government operation because of loss of productivity from automobile pollution outside of Washington, D. C., SMSA:
5. Loss of income tax payments by disabled workers;
6. Payments to disabled workers after 1969 who were disabled prior to 1970.

What is the cost of impaired lung development? We have observed this in second grade school children in the dirtier areas of Cincinnati and in the high NO_2 area of Chattanooga. Impaired lung development precedes chronic respiratory disease in adults. The incidence of A_2/Hong Kong/68 was higher in dirtier areas and influenza home confinement of second grade school children was significantly longer. Is this part of a submerged iceberg we cannot see?

This is not the complete answer. It is our first attempt and one which we present with misgivings. Our misgivings come from the inability of epidemiological studies to assess the relative contribution of relevant covariates.

Table 3

Value in January, 1970 loss of income tax due to premature death, social security payment to disabled workers, and loss of productivity in SMSA Washington, D. C.

(Million dollars)

	1953-1961	1962-1969	Total
Premature deaths	960.3	953.0	1,913.3
Social Security Payments	36.6[a]	152.8	189.4
Loss of productivity Washington, D. C.[b]	19.8[c]	77.3	97.1
TOTAL	1,016.7	1,183.0	2,199.8

a For years 1958-1961

b This estimate is based on a 10 percent reduction in productivity of federal government workers due to eye irritation from smog during hours oxidant concentrations are at or above the eye irritation threshold level at the CAMP station.

c For 1960 and 1961

INTRODUCTION

The health component of cost benefit analysis of air pollution is the most difficult to assess. Other major components are: (1) material damages and (2) agricultural crop and livestock damages. This report is the first halting step to quantify the health cost from a major pollutant source. It considers only direct cost to the Federal Government.

Many difficulties are encountered. Motor vehicles are not the only source of pollution. Epidemiological studies must (need to) assess the relative contribution of other pollutants as well as the contribution by the pollutant of interest. Many studies have used smoke shade, suspended particulate or some other measure as an index of air pollution level. Pollutants usually measured are those we know how to measure using relatively inexpensive instruments. Another serious problem is the location of air sampling stations. One or two stations located in the central city are generally all we have to characterize the ambient air of a city. These stations may be at ground level, on the top of buildings, or even on TV towers. The national air sampling network is designed to indicate trend over time but they are not designed to measure the difference in air pollution levels in two or more cities.

What about the effects of cigarette smoking and occupational exposure? Nonsmoking uranium miners and asbestos workers have a lung cancer rate similar to the population average for nonsmokers. Cigarette smokers among uranium miners and asbestos workers develop

lung cancer at a rate several times higher than the population average for smokers and a much younger age. This synergestic effect undoubtedly exists between other pollutants and cigarette smoking.

We know about acute effects of automobile pollution. Suicides and accidental deaths occur periodically from breathing automobile exhaust. What is the chronic effect from long time exposure to lower levels of motor vehicle pollution? Studies are complicated by smoking history, occupational exposure, population age structure, population mobility and residential exposure. We are just beginning to identify some of these factors qualitatively.

We do not expect experimental quantitative results. Mortality has not proved as useful as we had hoped. Even in an acute air pollution episode the first to die are the elderly with existing chronic diseases and difficulties. In an air pollution episode the chronic disease will be coded on the death certificate as the cause of death and not air pollution.

I. Emissions - Health Effects

Motor vehicle exhaust in 1965 accounted for 60 percent by weight of total national air pollution emissions[1]. The major emitted pollutants are: (1) hydrocarbons; (2) carbon monoxides; (3) oxides of nitrogen; and (4) lead compounds which are contained in emitted particulates. Oxidants are among the products formed from emitted pollutants by a complex system of atmospheric reactions between hydrocarbons and oxides of nitrogen initiated by sunlight. Automobile exhaust is the major source of pollutants which react photochemically to form oxidants.

Minor emitted pollutants from automobile exhaust are: (1) particulates other than lead compounds; (2) oxides of sulfur; and (3) trace elements, e.g. barium, boron and other fuel additives. The importance of the minor emitted pollutants depends on future use of fuel additives.

Registered passenger cars doubled between 1950 and 1967 (Figure 1), that is, the number of automobiles registered changed from 40 million to 80 million (Table 4). In like manner, fuel consumed on our highways increased from 36 billion gallons in 1950 to 78 billion gallons in 1967[2] (Figure 2). The American Automobile Manufacturers Association estimate that there will be 118 million passenger cars by 1975. This estimate is a three-fold increase in automobiles over 1950.

Road tests of 1966 automobiles equipped with exhaust control devices like those installed on new 1968 automobiles were conducted in five cities.

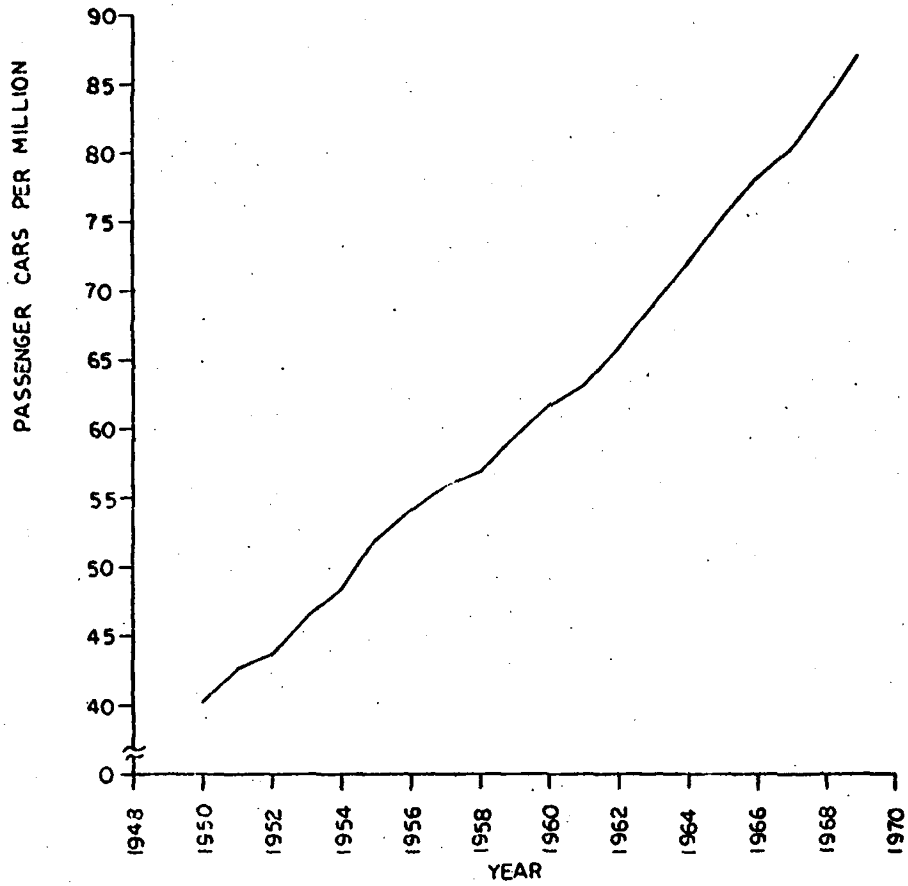

FIGURE I. REGISTERED PASSENGER CARS

Table 4

Registered Automobiles and Fuel Consumed

Year	Passenger Cars (000,000)	Fuel Consumption Highway (000,000,000)
1950	40.3	35.7
1951	42.7	38.1
1952	43.8	40.6
1953	46.4	42.7
1954	48.5	44.4
1955	52.1	47.7
1956	54.2	50.2
1957	55.9	51.9
1958	56.9	53.4
1959	59.5	56.3
1960	61.7	57.9
1961	63.3	59.3
1962	65.9	62.0
1963	69.0	64.5
1964	72.0	67.9
1965	75.3	71.1
1966	78.3	74.6
1967	80.3	77.7
1968	83.7	81.0*
1969	87.0*	84.3*

Source: Automobile Facts and Figures, Automobile Manufacturers Association, 320 New Center Building, Detroit, Michigan (1968)

* Estimated

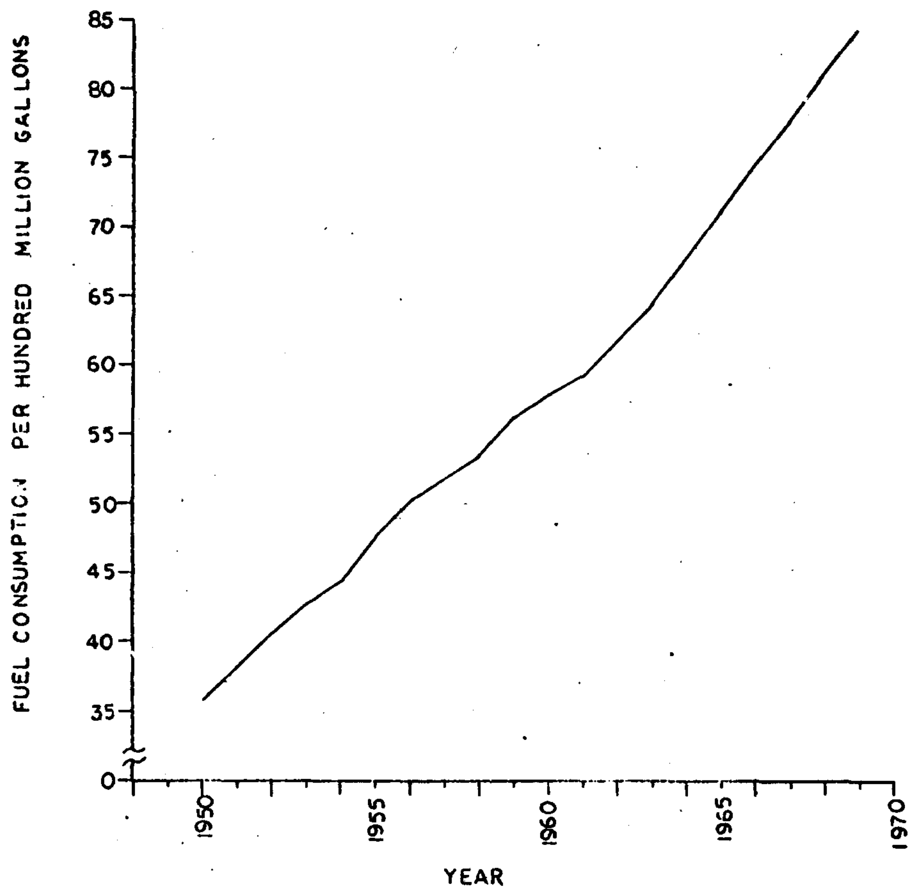

FIGURE 2
FUEL CONSUMPTION - HIGHWAYS.

Reductions in emissions were 67 percent for carbon monoxide and 35 percent for hydrocarbons while oxides of nitrogen increased 26 percent[3].

The build up in ambient air of pollutants other than oxides of nitrogen is tending to level off as a result of installation of pollution control devices. However, today only a little over one-fifth of the passenger cars registered are equipped with these devices.

A. Hydrocarbons - Health Effects

Automobile exhaust is the major source of hydrocarbons in our cities. In Los Angeles motor vehicle exhaust accounts for 90 percent of hydrocarbon emissions but drops to 70 percent in Washington, D. C., and New York City.

Hydrocarbons emitted in automobile exhaust contain known carcinogens and co-carcinogens which may have a synergistic effect. Approximately two-thirds of hydrocarbons emitted are from motor vehicles. The build up in hydrocarbon emissions during the past 10 years and the projected future emissions as a result of motor vehicle emission control are given in Figure 3.

Haenszel, et al[4] analyzed 2,191 lung cancer deaths among white American males occurring in 46 states. Adjusted for age and smoking history the mortality ratio of urban to rural was 1.43. The ratios increased with length of residence from 1.08 for residence less than a year to 2.00 for life time residence. Similar results were found among white females. Table 5 contains the findings of Buell and Dunn from a review of the evidence

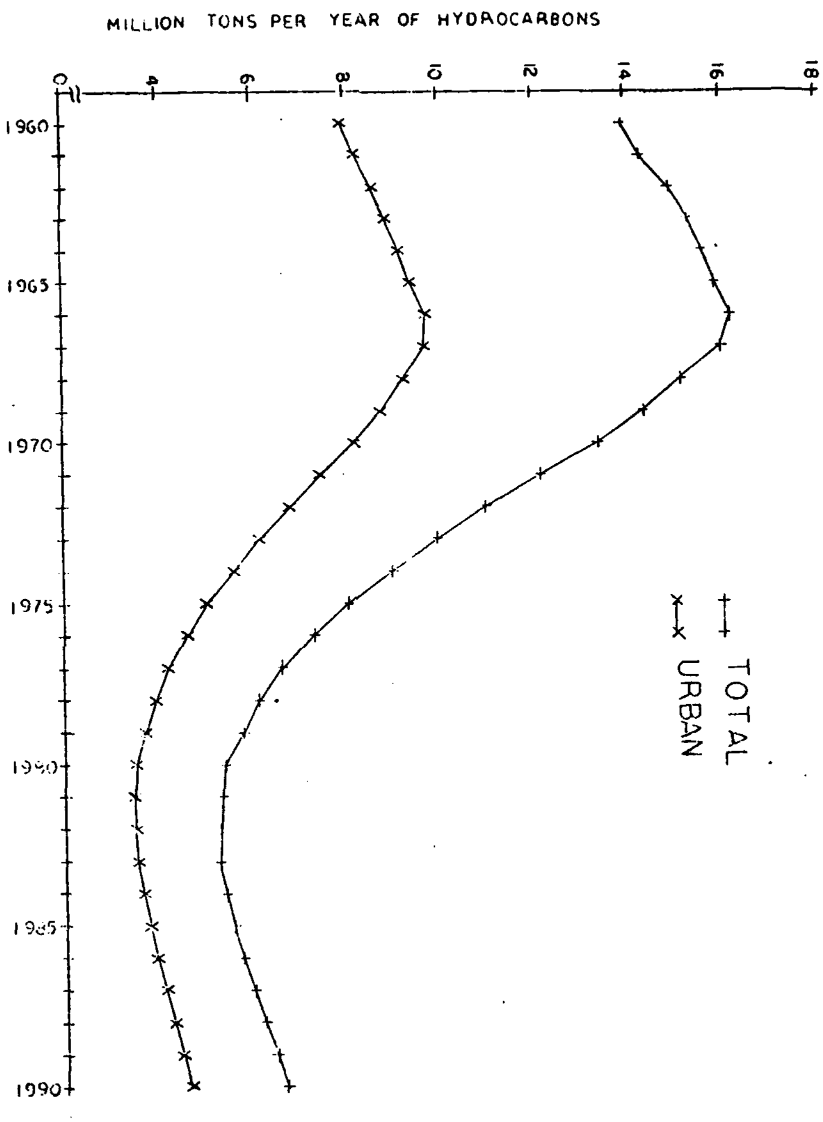

FIGURE 3 HYDROCARBON EMISSIONS

Table 5

Summary of lung cancer mortality studies death rates per 100,000 for lung cancer:

Standardized for age and smoking			Non-smokers		
Urban	Rural	U/R	Urban	Rural	U/R
101	80	1.26	36	11	3.27[a]
52	39	1.33	15	0	[b]
189	85	2.23	50	22	2.27[c]
			35	10	3.80[d]
149	69	2.15	23	29	.79[e]
100	50	2.00	16	5	3.20[f]

Source: Buell and Dunn[5]

'a' Buell, Dunn and Breslow, California men death rates by counties.

'b' Hammond and Horne, American men.

'c' Stocks, England and Wales.

'd' Dearr, Northern Ireland.

'e' Golledge and Wicken, England; no adjustment for smoking since no data on smoking was collected.

'f' Haenszel, et al, American men.

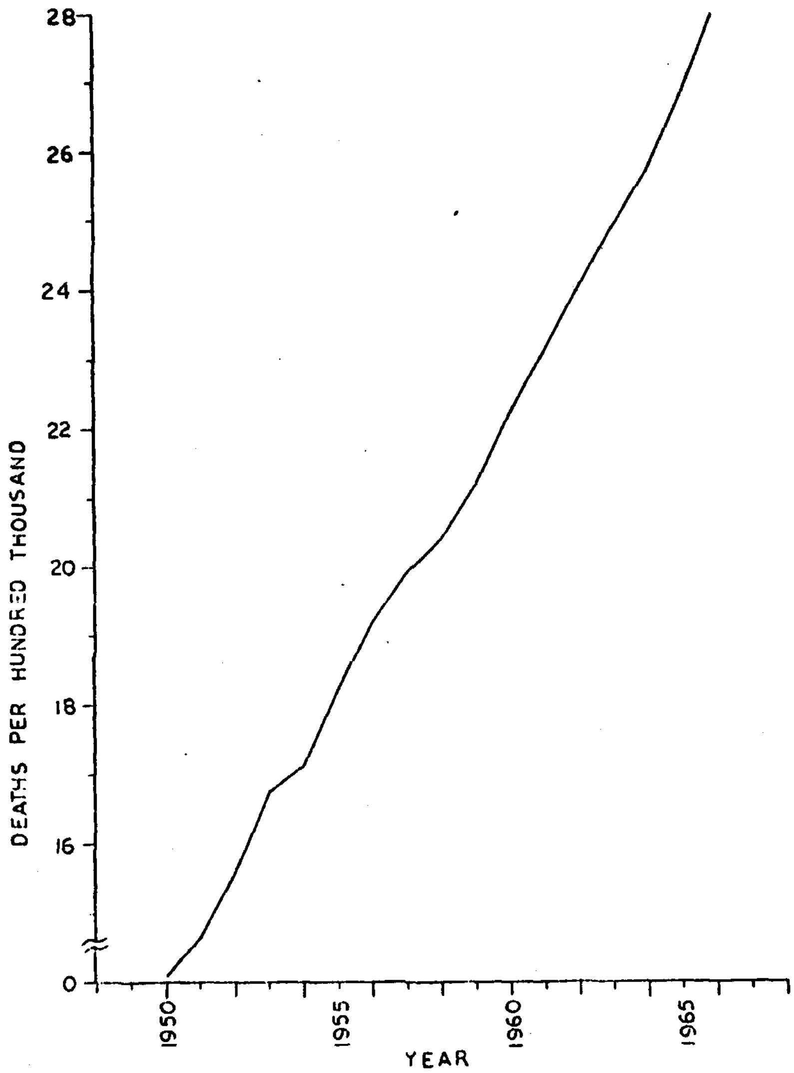

FIGURE 4
LUNG CANCER

on lung cancer and air pollution[5]. Smokers death rates adjusted for age and smoking history, ranged from 25 to 123 percent higher in urban than rural areas. All differences for non-smokers between rural and urban areas exceed 120 percent. The urban factor is evident when viewing non-smokers or adjusting for smoking history and the smoking factor is evident when viewing rural dwellers exclusively. The authors argue that difference in diagnosis quality cannot account for observed urban rural differences.

All of the studies point toward an urban and air pollution factor after standardizing for age and smoking habits. The rural urban difference can not be explained only in terms of population density and urban factor without considering air pollution also.

Mortality rates from lung cancer, number of registered passenger cars, and highway fuel consumption have all doubled since 1952 as can be seen from Figures 1, 2, and 4. From Figure 3, it is clear not all hydrocarbon emissions are in the cities, but about 40 percent are emitted in rural areas. Hence, some of the rural lung cancer deaths may be from hydrocarbon emissions from auto exhaust as well as from cigarette smoking.

From a review of studies shown in Table 5, it seems reasonable to say 50% of all current lung cancer deaths are due to an urban factor and air pollution. With the present state-of-the-art it appears that the air pollution effect is larger than other urban factors. However, we are assigning only fifty percent of excess urban lung cancer deaths to air pollution. Hence, approximately 25 percent of total lung cancer mortality

is ascribed to air pollution. Since two-thirds of the hydrocarbons emitted to the ambient air come from motor vehicles[1] it appears reasonable to assign two-thirds of 25 percent or 17 percent of lung cancer deaths to motor vehicle pollution. We are using an estimate of 10 percent which is conservative.

B. Carbon Monoxide - Health Effects

Carbon monoxide is a colorless, odorless gas. When inhaled it deprives man of part of his blood's oxygen-carrying capacity.

In 1965 motor vehicle exhaust accounted for 92 percent of all carbon monoxide (CO) emissions. Chovin[6], and Clayton et al[7], have shown that exposure to CO ambient air levels of 10-12 ppm for 4-5 hours increases carboxyhemoglobin (COHb) by 1.5 percent, that is from 0.5 to 2 percent. The emission of CO during the past decade and projected future emissions are shown in Figure 5.

According to the report of a special committee of the National Research Council on CO[8], COHb levels as low as 2 percent can cause certain impairment in mental functions. CO ambient air levels at several of our CAMP stations are sufficiently high to maintain a COHb level at or above 2 percent. For instance, the CAMP station in Chicago has recorded over one-half of the hourly averages at or above 12 ppm[9]. This is higher than needed to maintain a COHb level of 2 percent in the exposed population.

CO holds special hazards for high-risk medical groups including persons

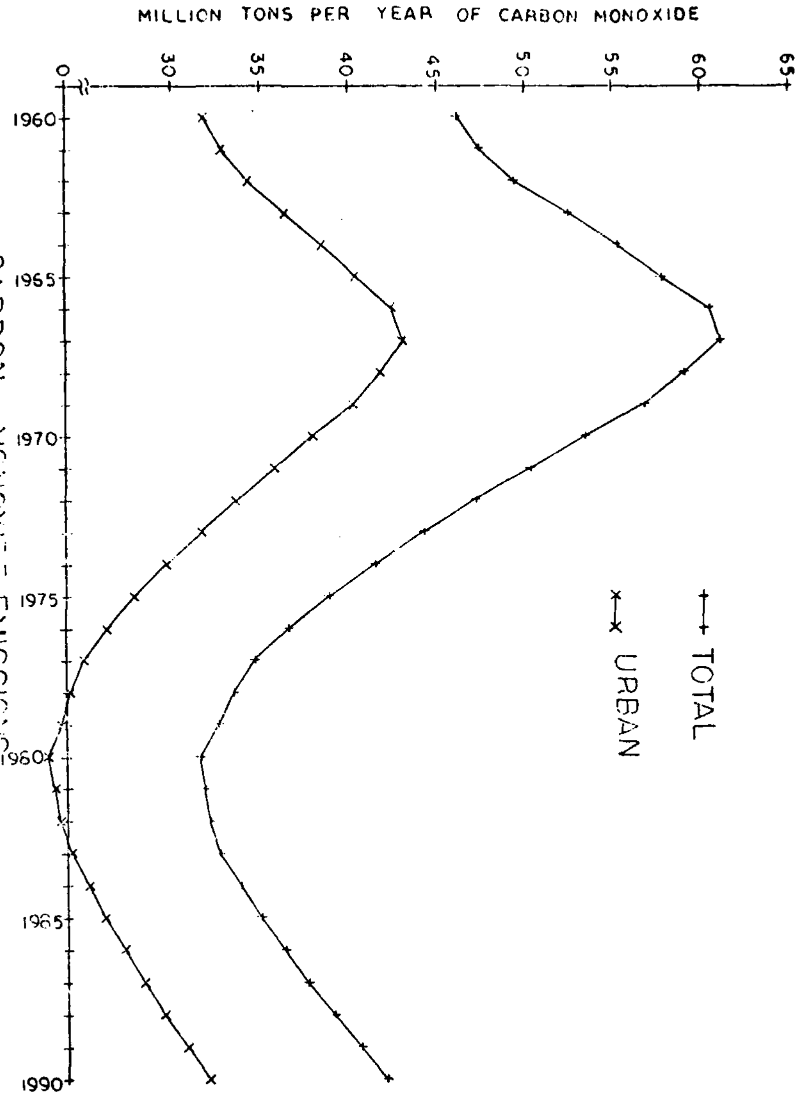

FIGURE 5

CARBON MONOXIDE EMISSIONS

SOURCE: DAQED, BCS, NAPCA, 12-9-69

with severe anemia, chronic pulmonary disease or impairment of circulation to vital organs. In addition recent evidence has suggested a slight increase in case-fatality rates among patients hospitalized with myocardial infarction when the CO level is consistently at about 10 ppm[10].

There is no level of CO in ambient air that is known to be without effect. A high damage function can be attributed to CO at the usual ambient air levels found for a significant part of the time in our major cities.

In addition to the groups proposed as sensitive groups, individuals requiring maximal judgemental and functional ability may be an important group to consider in discussion of health effects associated with CO. Automobile drivers are the largest group of individuals in this category.

The available data on CO effects upon visual sensitivity and accurate estimations of time intervals suggest a possible mechanism which could affect an individuals ability to drive a motor vehicle. These effects may be associated with as low as 2 percent COHb. Laboratory studies and the available epidemiologic information are consistent with the possibility that such an increase in COHb influences the frequency of accidents.

Cohen, et al[29] found that individuals who have a heart attack on a day with high CO concentrations have a poorer chance of survival than those who have an attack on a day with low CO concentrations.

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The California State Department of Public Health has studied the effects of carbon monoxide and concluded that the "major consequences can include interference with important functions of the central nervous system, and interference with acute vascular episodes such as heart attacks. Carbon monoxide at commonly occurring levels may have an effect on motor vehicle accidents. Increases of 2 percent carboxyhemoglobin or more in human subjects impair important central nervous system functions such as estimation of time intervals, visual perception, or performance of psychomotor tests. Such an increase could be produced from exposure to as little as an average of 10 ppm over a period of 24 hours. Four- to five-hour exposures will measurably increase the carboxyhemoglobin among non-smoking traffic policemen."

Chovin[6] found individuals involved in auto accidents had the highest blood CO level followed by workers with CO exposure, while individuals with suspected exposure in the house had the lowest blood CO levels. The number of blood samples in each of the three groups were: (1) 1672 blood samples; (2) 3818 blood samples; and (3) 15118 blood samples.

Over a span of many years, CO concentrations have been measured for a variety of relative short, isolated studies. In recent years, CO has been measured continuously at a relatively few locations (CAMP stations) in the United States.

MacMillan[11] found CO exposure reduced performance of swimmers who travel Los Angeles expressways on the way to the contest.

In summary, some effects of high carbon monoxide levels are:

1 reduction in judgemental and functional ability;

2 case fatality rates higher for patients hospitalized with myocardial infarction;

3 individuals who have a heart attack have a poorer chance of survival;

4 increased risk for patients with chronic pulmonary disease or impairment of circulation to vital organs; and

5 performance of swimmers and other athletes are reduced.

C. Oxidants - Photochemical Smog - Health Effects

Oxidants are among the products formed from emitted auto exhaust pollutants by a complex system of photochemical atmospheric reactions between hydrocarbons and oxides of nitrogen. Eye irritation from oxidants and photochemical smog is the best documented damage function from auto exhaust air pollution at the levels frequently found in ambient air. Renzetti and Gobran[12] conducted the first of several studies on a variety of individuals in various parts of Los Angeles. The results of these studies showed a relationship between increasing eye irritation and photochemical oxidant concentration over the range of 0.05 to 0.34 ppm. Other studies on eye irritation have all reported substantially the same results as Renzetti and Gobran. The studies indicated that the threshold level for eye irritation is about .1 ppm of oxidants in ambient air.

Schoettlin and Landau[13] studied the effects of oxidant levels on 157

asthmatic patients who lived and worked in the Pasadena area. They found a significant increase in the number of attacks when oxidant levels exceeded .13 ppm contrasted with days when oxidant levels were lower. There was also a significant association between attack rates on days in which plant damage occurred (oxidant concentration of about 0.10 ppm) in contrast to days without plant damage. The authors suggested that this may indicate a threshold level for oxidants above which there could be a physiologic response. This effect was most pronounced for persons who had lived in the area for 10 or more years.

Motley, et al[14] reported the results of lung function test on 66 volunteers, 46 of whom had pulmonary emphysema. No accurate measurements of oxidants were obtained, but during the period studied, oxidant concentrations ranged from .2 to .7 ppm and ozone from .2 to .53 ppm at a monitoring station several miles from the clean air chambers. Lung function tests were performed on subjects in rooms from which oxidants were removed by activated charcoal filters. Air was classified as smoggy when there was a defined odor of ozone, reduced visibility, eye irritation, and the prediction of smog by the Los Angeles Air Pollution Control District. An improvement in lung function was observed, particularly a decrease in the residual lung volume in emphysematous subjects who remained in the chamber for 40 or more hours and who entered it on smoggy days. No significant changes in lung volume measurements were obtained when normal patients breathed filtered air. No significant changes were observed when emphysematous subjects entered the chambers on non-smoggy days.

At Los Angeles County Hospital, Remmers and Balchum[15] used air conditioned rooms with filters which could be used at the investigators

discretion. Preliminary examination of the data indicated that airway resistance was affected by oxidant exposure over the range of .05 to 0.23 ppm. (Note of caution -- failure to control properly for cigarette smoking means results must be interpreted cautiously. Nevertheless, the majority of the non-smokers in this study did show decreases in airway resistance corresponding to decreases in oxidant exposure.)

Wayne, et al[16] reported on athletic performance in 21 competitive meets of high cross-country track runners at San Marino High School, Los Angeles County from 1959 to 1964. A significant relationship was observed between oxidant levels and the percent of team members whose performance decreased compared to their performance in the immediately previous home meet. The impairment of team performance occurred over the range of oxidant concentrations from 0.05 to 0.30 ppm; there were, however, no oxidant measurements between .1 and .2 ppm.

Ury[17] studied the association of automobile accidents with days of elevated oxidant levels on the possibility that oxidant pollution may impair performance either directly by interferring with oxygen transport, or indirectly by eye discomfort and respiratory irritation. There were significantly more accidents when oxidant concentrations ranged from 0.01 to 0.50 ppm. At the same time that oxidant concen-trations all high, carbon monoxide, oxides of nitrogen, hydrocarbons, and concentrations of other auto exhaust gases are also elevated. Since CO will usually lie within the range which might affect an individual's reaction time, it is not certain which exhaust product is responsible for the re-sults of the study. However, oxidants or carbon monoxide or both may be indicated.

McCarroll et al[18] reported a substantial increase in the frequency of eye irritation reports as oxidant levels in ambient air increased in mid-town Manhattan. It is possible that eye irritation symptoms in New York City result from mixed pollution of both oxidizing and reducing type. It is clear that auto exhaust and photochemical oxidants are present in New York City. These result in the same physical reactions found in Los Angeles.

A joint committee of the Los Angeles County Medical Association and the Tuberculosis and Health Association of Los Angeles County[19] carried out a survey of physicians in December, 1960. Seventy-seven percent of the physicians believed that air pollution adversely affected the health of their patients. One-third had advised one or more of their patients to leave the Los Angeles area for health reasons -- air pollution was mentioned specifically in two-thirds of the reports. Over 10,000 families were advised to leave during the year. From this group, 2,500 families moved.

Some effects of high oxidant levels are:

1 eye irritation;
2. increase in number of asthmatic attacks;
3. decrease in lung function test on pulmonary emphysema patients;
4. increase in airway resistance test;
5. impairment of athletic performance in competitive meets of cross-country track runners in L. A. County; and
6. significant increase in automobile accidents.

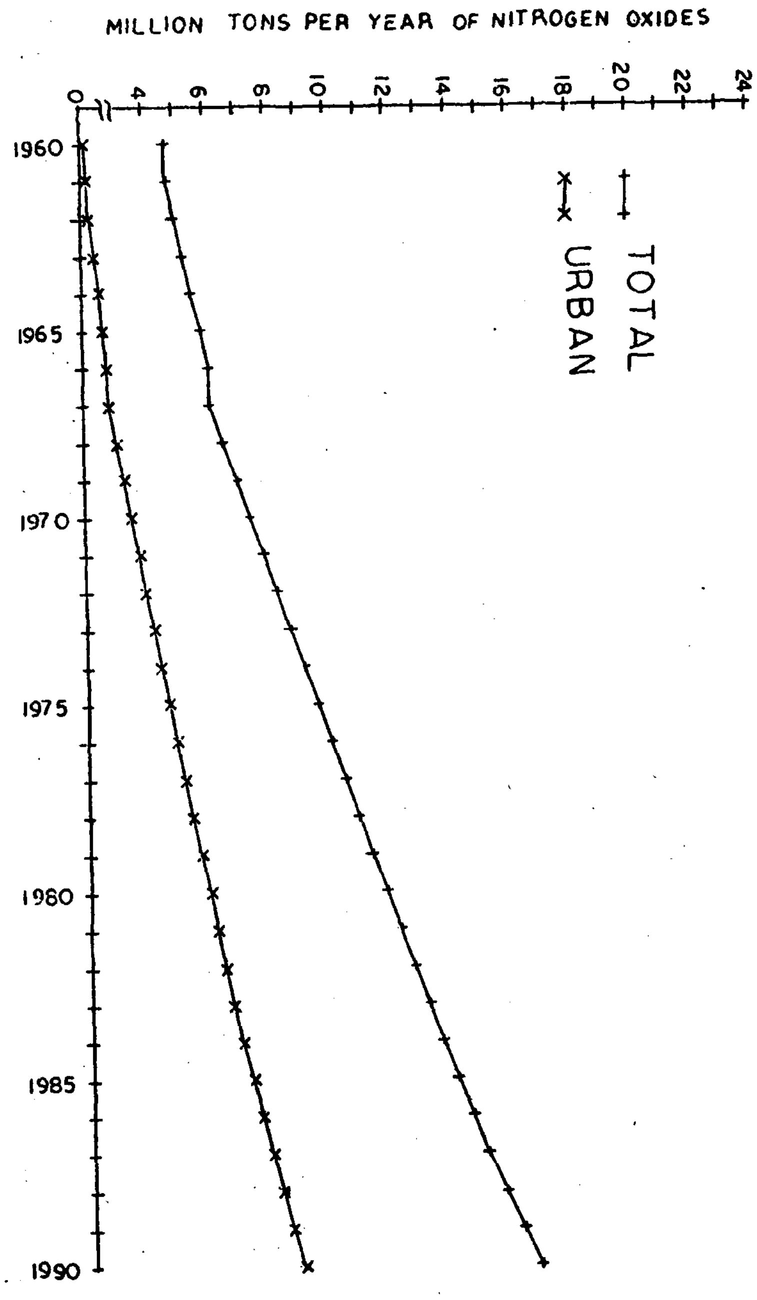

FIGURE 6 OXIDES OF NITROGEN EMISSION

SOURCE: DAQED, BCS, NAPCA, 12-9-69

D. Oxides of Nitrogen - Health Effects

Oxides of nitrogen differ from the other pollutants in that at present only a little over 50 percent of all emissions come from motor vehicles. This is important since the current exhaust emission control devices, while reducing hydrocarbons and carbon monoxide, increase emission of oxides of nitrogen. Also, there is likely a delayed reaction to nitrogen oxides, as compared with exposure to other irritating pollutants. Animal studies give strong suggestive evidence that long term low level exposures lead to structural changes resembling emphysema. Figure 6 shows emissions of oxides of nitrogen since 1960 and a projected further increase during the next 10 years.

Shy et al[21] completed a study of selected health characteristics among more than 850 second grade school children from Chattanooga, Tennessee residential areas with a NO_2 gradient in ambient air. The volunteer study population was recruited from four residential sectors. The two control sectors were lower in both particulate and NO_2 than either of the polluted areas. One of the other two sectors was high in NO_2 and low in particulate and the other high in particulate and low in NO_2.

The socioeconomic factors considered were house value or rent, education of head of household, and crowding. In each case, the high NO_2 exposure sector exhibited the highest socioeconomic level followed by control sectors. The low NO_2-high particulate exposure sector had a distinctly lower socioeconomic level. Home cigarette smoking in the control sector and high NO_2 sector differed by only one percent.

Acute respiratory disease prevalence was monitored for 24 weeks from November 1968 to April 1969. These indicators were: (1) acute respiratory prevalence in entire family, (2) acute respiratory prevalence in second grade school children. These were both significantly less in the two control sectors than in the polluted sectors. The length of home confinement was not significantly different in the sectors.

Two epidemic waves of acute respiratory illness were observed; illness during each of these waves was prospectively reported. The first in late 1968 was caused by A_2/Hong Kong/68 influenza and the second in the spring of 1969 was probably related to B influenza.

Length of home confinement of second grade children was significantly larger in the high NO_2 sector. The incidence was 13 percent higher per person per season in the high NO_2 and high particulate sectors. The increased fever per person per season and physician visit per person per season was 20 percent higher in the polluted sectors than in the control sectors.

These results are consistent with Finklea et al[22] who reports increased influenza A_2 and non-influenzal acute respiratory morbidity among heavy cigarette smokers. Petr and Schmidt[30] in Czechoslovakia observed an average of 2.5 percent methemoglobin in the blood of the children near a factory with nitrous gases (concentration ranging from 20 to 70 $\mu g/m^3$) compared with an average 0.86 percent methemoglobin for the children who were not near any air pollution source.

Kapalin[31] studying the children in the same towns found greatly enlarged cervical glands in 42 to 43 percent of the children in the polluted towns compared to 8 percent in the clean town.

Some effects of high NOx levels are:

1. animal studies suggest that emphysema may be caused by NOx;
2. acute respiratory disease prevalence in second grade school children was 15 to 20 percent higher;
3. acute respiratory disease prevalence in entire family was 15-20 percent higher;
4. epidemic wave of A_2/Hong Kong/68 influenza was 15 to 20 percent greater (prospectively reported.)

E. Lead - Health Effects

Lead is widely distributed in man's environment. It is found in his food, water, and the air he breathes. Today two major uses of lead are for storage batteries and gasoline additives with substantial amounts used in pigments, pesticides, plumbing, pottery glazes, and solder.

Diet seems to be the major source of human lead exposure. From this intake of lead 90 to 95 percent is excreted in feces; hence, most ingested lead is not absorbed by the body.

Amount of lead absorbed in the respiratory tract is a function of the particle size, solubility, and route. About 25 to 50 percent of inhaled

lead from motor vehicle exhaust is thought to be absorbed. Lead from other sources usually has a larger particle size which results in a smaller proportion being absorbed. The body burden is mostly deposited in bone and soft tissue.

Inorganic lead in sufficient amounts is implicated as a causative agent in decreased hemoglobin synthesis, liver and kidney damage, mental retardation in children, and abnormalities of fertility and pregnancy[23]. Goldsmith reports an increasing concentration of lead with age in liver, spleen, pancreas, kidney, and lung for U. S. population samples.

Goldsmith and Hexter[24] have presented data showing blood lead levels to be epidemiologically related to estimated respiratory exposure in areas with high levels of motor vehicle pollution. The authors contend that *total body burden* is, *in* part, a function of respiratory exposure. The implications are that continued exposure to ambient air lead levels in many of our cities is resulting in an increased body burden as indicated by blood lead.

F. Minor emitted pollutants - Health Effects

These are not discussed further since their importance depends on their use as fuel additives.

II. Cost to the Federal Government

What are the direct costs to the federal government from health effects

damage as a result of motor vehicle exhaust? First, auto exhaust is a mixture of gases. The most important of these discussed in the preceding section are: (1) carbon monoxide, (2) hydrocarbons, (3) oxides of nitrogen, (4) lead products, and (5) oxidants which are formed by a complex photochemical process and emitted gases such as NOx and hydrocarbons.

What are some of the results of urban concentrations of the above pollutants? Some health effects from these pollutants are: (1) more auto accidents occur on days of high oxidant levels; (2) drivers of autos involved in accidents have a higher concentration of CO in the blood than non-accident drivers or the general public; (3) a 2 percent carboxyhemoglobin concentration can reduce mental functions and ability to judge small time intervals, which may account for a greater number of auto accidents; (4) CO holds special hazards for high-risk medical groups including persons with severe anemia, chronic pulmonary disease, impairment of blood circulation to certain vital organs; (5) recent evidence suggests an increase in case fatality rates among hospital patients with myocardial infarction when CO concentration is about 10 ppm or higher; (6) reduced performance of athlete, and more frequent headaches are associated with photochemical oxidants; (7) eye irritation from photochemical oxidants and pollution starts at a concentration which is one-half the level found at the CAMP stations in Los Angeles for 10 percent of the time; (8) asthma patients suffer more frequent asthmatic attacks on days with high oxidant concentrations; (9) it is harder for humans especially persons suffering from chronic respiratory disease to breathe in areas with moderate levels of photochemical air pollutants; (10) certain com-

ponents of hydrocarbon emissions are known to be carcinogenic and co-carcinogenic; (11) significantly greater number of automobile accidents occur on days of high oxidant levels; (12) increases in airway resistance tests are found on days when oxidant levels are high; (13) results of animal studies suggest that continuous exposure to ambient air levels of NOx may cause emphysema; (14) acute respiratory prevalence is 15-20 percent higher in high NOx areas compared to control areas; (15) epidemic waves of A_2/Hong Kong/68 influenza (prospectively reported) and home confinement was 15-20 percent greater in the NOx area than the control area; and (16) ratio of lung cancer death rates in urban areas to those in rural areas adjusted for age and smoking is around 2.

Only the most obvious costs are considered in the following section.

A. Method for calculating present value of lost income tax because of premature death.

The first direct cost considered is loss of income taxes because of death. It is clear, however, that the sum of expected past and expected future income taxes of an individual is not the present value of income tax which these people would have paid had they lived a normal life. As long as a positive rate of interest prevails past expected income tax payments are subject to compound interest at the going rate and future expected tax payments must be discounted by prevailing interest rates. Actual dollars are used without using the consumer price index to adjust to current dollars. Two sets of adjustments were made.

The first step was to take the 1960 life table from Vital Statistics of the United States and modify it. If 'y' percent of deaths from disease "x" are due to motor vehicle pollution then by cleaning up pollution deaths from disease "x" are reduced by 'y' percent. New life tables were generated for each 5 year age interval and both sexes which reduced by 'y' percent mortality rates for disease "x". New life tables were made for each disease category considered in this paper. These were: (1) lung cancer (ICD 160-161); (2) heart disease (ICD 420); (3) bronchitis (ICD 500-502, 525-527); and (4) motor vehicle accidents (ICD E810-E835).

If the 'y' percent of the people had not died from disease "x" but had lived a normal life, they would have paid income taxes like normal individuals from the same age cohorts. Present value of all income taxes which would have been paid are needed. The calculations were made in two steps. Step one calculated the present value of income taxes which would have been paid before 1970, had these people lived a normal life. Actual tax rates were used and average income for each year. Compound interest at 6 percent was added to arrive at the present value. Step two used an average increase in salaries of 4 percent per year after 1970. Since 1952 the average wage increase has been 4 percent for males and 6 percent for females. The estimated income tax was discounted at 6 percent rate.

These concepts for cal ulating present value of loss in income tax payments

are given in the formula:

$$V = \sum_{Y=1953}^{1969} \sum_{s=m}^{f} \sum_{x=1}^{15} \sum_{t=1}^{75-x} {}_{y}L^{s}_{x+t}\, E^{s}_{y+t}\, R_{y+t}\, A^{s}_{x+t}\, F^{s}_{x+t}\, (1.06)^{1970-y-t}$$

where

V is present value in actual dollars (has not been adjusted for consumer price index);

y is year of death;

s is sex - male or female;

x is 5 year age increment, e.g. x = 1 for age 0-4, x = 2 for age 5-9, etc.;

t number of years after death - x as used in 75-x is 2, 7, 12,...., 72;

${}_{y}L^{s}_{x+t}$ is the number of resurrected deaths alive in year y+t at age x+t and sex s - this is based on revised life table;

E^{s}_{y+t} is average income for year y+t, sex s;

R_{y+t} is tax rate for year y+t

A^{s}_{x+t} is age-adjusted income for age y+t, sex s;

F_{x+t} is age-adjusted tax rate for age x+t; and

$(1.06)^{1970-y-t}$ is accumulation or discount factor for interest rate y is year of death, t is number of years after death.

This formula is a modification of the one used by Ridker.[26]

B. Lung cancer - loss of income tax because of premature death (ICD 500-502, 525-527)

The cost to the federal government is based on 10 percent of the deaths from lung cancer being caused by motor vehicle exhaust. The justification for the 10 percent estimate was developed in the preceding section.

The present values of income tax which would have been paid "after death," by 10 percent of the people who died from lung cancer had they lived a normal life is given in Table 6. This is a total of $270.9 million. In the same table, the income tax loss is given for the period before 1970; and for the period 1970 and after for males, females and both.

Table 7 shows the same present value of income tax for age at death broken into 5 year age intervals for each sex. Only 13 percent of the loss of income tax payments occurs in the age group of 60 and ov··

Present values of income tax which would have been paid "after death" had these people lived normal lives are shown in Table 8. These are broken down into values by sex and year of death.

The values in this table may be used to calculate values for any desired combination of years. Also, one may use Table 8 and change the percentage attributed to motor vehicle pollution.

C. Bronchitis - loss of income tax because of premature death (ICD 500-502, 525-527)

This group includes acute bronchitis, bronchitis unqualified, chronic bronchitis, bronchitis with emphysema, other diseases of lung and pleural cavity.

Table 6 Lung Cancer (ICD 160-164)

Value in January, 1970 of Federal Income Tax which would have been paid "after death" by 10% of the people who died in 1953-1969 from lung cancer, had they lived normal lives. Actual dollars.

(Millions of dollars)

	Male	Female	Total
Taxes paid before 1970	165.6	7.08	173.7
Taxes paid in 1970 and after	91.4	6.10	97.2
TOTAL	257.0	13.18	270.9

(1) 1960 death rates, eliminating 10% of lung cancer rates.
(2) Consumer price index not used; after 1970, a wage increase of 4% per year is assumed. (Since 1952, the increase has been 4-1/2% per year for males and 6% per year for females.)
(3) Accumulation rate (before 1970) and discount rate (after 1970) both equal 6%.
(4) Average income and tax rate factors used (by year).
(5) Age adjustments made for income, tax rate, and unemployment rate.

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Table 7. Lung Cancer (ICD 160-164)

Value in January, 1970 by age group at death and sex for 10% of lung cancer deaths (ICD 160-164)

(Millions of dollars)

Age Group	Male	Female	Total
30-34	6.40	.63	7.03
35-39	15.9	1.50	17.4
40-44	32.4	2.64	35.0
45-49	50.4	3.27	53.7
50-54	62.4	2.68	65.1
55-59	54.3	1.64	55.9
60-64	28.6	.66	29.3
65-69	6.20	.15	6.35
70-74	.4	.01	.39
TOTAL	257.0	13.2	270.2

Table 8. Lung Cancer (ICD 160-164)

Value in January, 1970 by year of death and sex
for 10% of lung cancer deaths (ICD 160-164)

(Millions of dollars)

Year of Death	Male	Female	Total
1953	12.2	.48	12.7
1954	12.4	.47	12.9
1955	13.0	.52	13.5
1956	13.6	.54	14.2
1957	13.8	.56	14.3
1958	14.1	.61	14.6
1959	14.4	.63	15.0
1960	14.8	.67	15.4
1961	15.2	.73	15.9
1962	15.6	.76	16.4
1963	15.7	.86	16.6
1964	16.1	.88	17.0
1965	16.6	.97	17.6
1966	17.0	1.03	18.1
1967	17.3	1.11	18.4
1968	17.6	1.15	18.8
1969	17.6	1.18	18.8
TOTAL	257.0	13.2	270.2

Table 9 shows the present value for taxes paid before 1970 and for taxes paid in 1970 and after by sex for 10 percent of the people who died in 1953-1969 from bronchitis.

Values in January, 1970 by sex and age group at death for 10 percent of bronchitis deaths are shown in Table 10.

Table 11 shows values in January, 1970 by year of death and sex for 10 percent of bronchitis deaths. This permits regrouping of years into new combinations and to change the percentage of deaths resurrected so the percentage may vary from year to year.

D. Arteriosclerotic heart disease including coronary disease - loss of income tax because of premature death (ICD 420)

As shown in the preceding section individuals with reduced circulation to any organs are sensitive to high CO levels and high photochemical oxidant levels. Also, high photochemical oxidant levels reduces the rate of survival of myocardial infarction patients. Goldsmith and Landau[32] found case fatality rate for patients with myocardial infarction and ambient CO concentration, by day of week, had a correlation of .16. This study used data on 1958 hospital admissions for the Los Angeles area. Correlation coefficient of .16 says that 2.5 percent of the variation the fatality rate is associated with ambient CO level; since .16 squared equals to .0256. We have attributed 2.5 percent of deaths from arteriosclerotic heart disease and coronary disease to motor vehicle emissions. This is a conservative figure. The actual level may be two to four times this level or higher. Friedman[33] correlated proportion of males, 45-64 living

in urban areas with coronary heart disease in 33 states. The simple correlation of .79 changed to a partial correlation of .67 when cigarette consumption was held constant. From this study 45 percent of coronary mortality is associated with urbanization and air pollution.

Table 12 shows the present value of federal income tax by sex which would have been paid before 1970 and in 1970 and after by 2.5 percent of the people who died in 1953-1969. The present value is $427.0 million.

Present value of lost income tax by age group at death and sex is shown in Table 13 for each 5 year age group.

Table 9. Bronchitis (ICD 500,502, 525-527)

Value in January, 1970 of Federal Income Tax which would have been paid "after death" by 10% of the people who died in 1953-1969 from Bronchitis had they lived normal lives.

(Millions of dollars)

	Male	Female	Total
Taxes paid before 1970	45.1	3.5	48.6
Taxes paid before and after 1970	65.0	11.9	76.9
TOTAL	110.1	15.4	125.5

(1) 1960 death rates, eliminating 10% of Bronchitis rates.
(2) Consumer price index not used; after 1970, a wage increase of 4% per year is assumed. (Since 1952, the increase has been 4-1/2% per year for males and 6% per year for females.)
(3) Accumulation rate (before 1970) and discount rate (after 1970) both equal 6%.
(4) Average income and tax rate factors used (by year).
(5) Age adjustments made for income, tax rate, and unemployment rate.

Table 10. Bronchitis (ICD 500-502, 525-527)

Value in January, 1970 by age group at death and sex for 10% of Bronchitis deaths (ICD 500-502, 525-527)

(Millions of dollars)

Age Group	Male	Female	Total
0-4	35.6	7.80	43.4
5-9	1.75	.52	2.27
10-14	.89	.22	1.11
15-19	.99	.27	1.26
20-24	.99	.30	1.29
25-29	1.19	.36	1.55
30-34	1.95	.55	2.50
35-39	3.80	.85	4.65
40-44	6.84	1.08	7.92
45-49	10.6	1.19	11.8
50-54	14.6	1.06	15.7
55-59	16.3	.73	17.0
60-64	11.3	.35	11.7
65-69	3.05	.09	3.14
70-74	.24	.01	.25
TOTAL	110.1	15.4	125.5

Table 11. Bronchitis (ICD 500-502, 525-527)
Value in January, 1970 by year of death and sex
for 10% of Bronchitis deaths (ICD 500-502, 525-527)

(Millions of dollars)

Year of death	Male	Female	Total
1953	4.30	.82	5.12
1954	4.29	.81	5.10
1955	4.72	.89	5.61
1956	5.28	.94	6.22
1957	5.88	1.04	6.92
1958	6.11	.93	7.04
1959	5.94	.87	6.81
1960	6.19	.83	7.02
1961	6.90	.90	7.80
1962	7.48	.92	8.40
1963	7.87	.97	8.84
1964	7.51	.92	8.43
1965	7.73	.95	8.68
1966	7.80	.95	8.75
1967	7.51	.90	8.41
1968	7.35	.88	8.23
1969	7.20	.86	8.06
TOTAL	110.1	15.4	125.5

Table 12. Heart Disease (ICD 420)

Value in January, 1970 of Federal Income Tax which would have been paid "after death" by 2.5% of the people who died in 1953-1969 from heart disease deaths; had they lived normal lives.

(Millions of dollars)

	Male	Female	Total
Taxes paid before 1970	268.7	15.1	283.8
Taxes paid in and after 1970	135.5	7.8	143.3
TOTAL	404.1	22.9	427.0

(1) 1960 death rates, eliminating 2.5% of heart disease rates.
(2) Consumer price index not used; after 1970, a wage increase of 4% per year is assumed. (Since 1952, the increase has been 4-1/2% per year for males and 6% per year for females.)
(3) Accumulation rate (before 1970) and discount rate (after 1970) both equal 6%.
(4) Average income and tax rate factors used (by year).
(5) Age adjustments made for income, tax rate, and unemployment rate.

Table 13. Heart Disease (ICD 420)

Value in January, 1970 by age group at death
and sex for 5% of heart disease deaths (ICD 420)

(Millions of dollars)

Age Group	Male	Female	Total
0-4	.20	.04	.24
5-9	.08	.01	.09
10-14	.10	.02	.12
15-19	.37	.05	.42
20-24	1.03	.14	1.17
25-29	3.40	.31	3.71
30-34	11.15	.76	11.91
35-39	29.8	1.62	31.42
40-44	57.5	2.98	60.48
45-49	81.25	4.17	85.42
50-59	90.6	4.78	95.38
55-59	75.55	4.29	79.84
60-64	41.6	2.73	44.33
65-69	10.6	.90	11.5
70-74	.87	.09	.96
TOTAL	404.1	22.9	427.0

Table 14. Heart Disease (ICD 420)

Value in January, 1970 by year of death and sex
for 5% of heart disease deaths (ICD 420)

(Millions of dollars)

Year of Death	Male	Female	Total
1953	23.5	1.23	24.8
1954	23.4	1.20	24.6
1955	23.7	1.22	24.8
1956	24.0	1.23	25.2
1957	24.4	1.30	25.7
1958	24.4	1.31	25.6
1959	24.4	1.30	25.6
1960	24.3	1.32	25.6
1961	24.3	1.36	25.6
1962	24.1	1.38	25.5
1963	24.2	1.43	25.6
1964	23.9	1.42	25.2
1965	23.7	1.44	25.2
1966	23.7	1.47	25.2
1967	23.2	1.46	24.6
1968	22.9	1.41	24.4
1969	22.4	1.41	23.8
TOTAL	404.1	22.9	427.0

Table 14 gives the present value of income tax which 5 percent of the people who died from arteriosclerotic heart disease including coronary would have paid had they lived a normal life. The present value is given for the cohorts dying each year.

E. Motor Vehicle accidents - loss of income tax because of premature death (ICD E810-E835)

Using 10 percent of deaths from motor vehicle accidents as the proportion of deaths due to motor vehicle emitted pollutants is probably conservative, since automobile accidents have been shown to occur more frequently on days with high ambient air oxidant levels and blood CO levels have been found to be higher in drivers of automobiles involved in accidents than drivers of cars not involved in accidents.

Table 15 shows the present value of income tax payments which would have been paid "after death," before 1970 and in 1970 and after by males, females and both.

Present value of lost income tax payments by sex and age group at death is shown in Table 16 for 10 percent of motor vehicle accidents.

The present value of lost income tax payments because of premature deaths are shown in Table 17 by year of death. The total present value of lost income tax payments is $1.086 billion.

Table 15. Motor Vehicle (ICD E810-E835)

Value in January, 1970 of Federal Income Tax which would have been paid "after death" by 10% of the people who died in 1953-1969 from Motor Vehicle accidents, had they lived normal lives.

(Millions of dollars)

	Male	Female	Total
Taxes paid before 1970	283.3	18.5	301.8
Taxes paid after 1970	723.4	60.8	784.2
TOTAL	1,006.7	79.3	1,086.0

(1) 1960 death rates, eliminating 10% of motor vehicle death rates.

(2) Consumer price index <u>not</u> used; after 1970, a wage increase of 4% per year is assumed. (Since 1952 the increase has been 4-1/2% per year for males and 6% per year for females.)

(3) Accumulation rate (before 1970) and discount rate (after 1970) both equal 6%.

(4) Average income and tax rate factors used (by year).

(5) Age adjustments made for income, tax rate, and unemployment rate.

Table 17. Motor Vehicle (ICD E810-E835)
Value in January, 1970 by year of death and sex for 10%
of Motor Vehicle deaths (E810-835)

(Millions of dollars)

Year of death	Male	Female	Total
1953	60.0	4.21	64.2
1954	55.5	3.85	59.4
1955	59.5	4.20	63.7
1956	60.6	4.25	64.9
1957	57.2	4.13	61.3
1958	53.6	3.89	57.5
1959	53.9	4.04	57.9
1960	52.8	4.06	56.9
1961	54.3	4.29	58.6
1962	53.7	4.40	58.1
1963	56.6	4.63	61.2
1964	59.8	5.09	64.9
1965	62.3	5.22	67.5
1966	66.8	5.67	72.5
1967	65.5	5.59	71.1
1968	66.7	5.78	72.5
1969	67.8	5.95	73.8
TOTAL	1,006.7	79.3	1,086.0

Table 18. SOCIAL SECURITY PAYMENTS[a]

YEAR	Disability Allowed					Current Pay Status			Current Pay Status		Average Yearly Payment	1970 value at 6% Compound Interest	1970 Value	
	TOTAL	ICD CODE 420[a]		ICD CODE 500-502[b] 525-527		TOTAL	ICD CODE 420	ICD CODE 500-502 525-527	ICD CODE 420	ICD CODE 500-502 525-527			ICD CODE 420	ICD CODE 500-502 525-527
	No.	No.	%	No.	%	No.	No.	No.	No. (2.5%)	No. (10%)			($000)	($000)
57	165,003	29,920	18.1	10,070	6.1	149,850								
58	184,478	32,830	17.8	11,852	6.4	287,719	51,663	17,964	2,583	1,796	985.20	2.0121	2,560	3,560
59	178,952	34,172	19.1	13,008	7.3	334,443	60,587	21,375	3,029	2,138	1,068.00	1.8983	3,070	4,335
60	179,419	35,685	19.9	13,647	7.6	455,371	84,652	30,656	4,231	3,066	1,071.79	1.7908	4,060	5,865
61	241,060	43,814	18.2	17,695	7.8	618,075	115,078	43,347	5,754	4,335	1,075.03	1.6895	5,226	7,874
62	236,434	49,023	17.1	21,319	7.5	740,867	136,567	52,556	6,828	5,256	1,079.98	1.5938	5,876	9,047
63	224,229	41,168	18.4	16,095	8.5	827,014	152,418	59,878	7,621	5,988	1,087.08	1.5036	6,228	9,788
64	209,475	39,425	17.3	14,789	6.5	894,000	164,007	64,232	8,200	6,423	1,093.44	1.4185	6,360	9,962
65	267,734	45,529	17.0	18,379	6.9	988,000	179,987	70,718	8,999	7,072	1,276.56	1.3382	7,686	12,081
66			18.0		7.1	1,097,000	198,557	77,887	9,928	7,789	1,250.88	1.2625	7,840	12,300
67			18.1		7.1	1,194,000	216,114	83,580	10,806	8,358	1,223.88	1.1910	7,676	12,183
68			18.1		7.1	1,295,000	234,395	90,650	11,720	9,065	1,342.32	1.1236	8,838	13,572
69			18.1		7.1	1,396,000	252,676	99,116	12,684	9,912		1.06	8,965	14,103
TOTAL													74,608	114,750

Source: Social Security Reports[27,28].

a Arteriosclerotic heart disease including coronary (ICD 420)

b Acute and chronic bronchitis and emphysema (ICD 500-502, 525-527)

F. Disability payments by Social Security Administration to workers who have not reached 65 years of age.

So far, cost to the federal government has been based on the present value of income tax which would have been paid "after death" if the people affected by motor vehicle emissions had lived a normal life.

Another direct cost to the federal government is social security payments to disabled workers who have not reached 65 years of age. Acute and chronic bronchitis and emphysema have been selected from the respiratory group as a subgroup related to automotive pollution.

The total number of requests for disability allowed, the number of requests allowed for heart disease (ICD 420) and the number of requests allowed for bronchitis and emphysema are given in Table 18 for 1957-1965. The total number of disabled workers in current pay status was available for years 1958-1962. The number in current pay status for years 1963-1969 had to be estimated from the total in current pay status and the proportion of requests for disability allowed for each disease.

Disability is defined by Social Security as: "the inability to engage in any substantial gainful activity by reason of any medically determinable physical or mental impairment which can be expected to result in death or to be long continued and indefinite duration prior to age 65 and to have existed for 6 months"[37,28].

The same justification for attributing 10 percent of bronchitis deaths and 5 percent of arteriosclerotic and coronary deaths to motor vehicle pollution is used for attributing the same percentage of disabled workers receiving social security payments to motor vehicle exhaust.

Table 18 shows the original data, the number of workers in current pay status, the number attributed to motor vehicle exhaust, average yearly payment, correction factor for converting actual payments to current value at 6 percent compound interest, and the last 2 columns give the 1970 value of yearly payment to the proportion of disabled workers which are attributed to motor vehicle pollution. Total disability payment for heart disease is $74.6 million and for bronchitis, $114 million.

The values in Table 18 are underestimates because on consideration is given for payments in 1970 and beyond. Some of the disabled workers will continue to be disabled until they reach 65 which extends beyond 1970 for many.

Another underestimation is the loss of income taxes which this group would have paid had they lived a normal life and not been disabled by motor vehicle pollution. This has not been evaluated but it is a sizable amount.

Workers disabled by motor vehicle accidents and by other diseases which may be attributed to motor vehicle pollution have not been considered or evaluated. However, the total of these would add up to a significant figure.

36-993 O - 74 - 9

G. Lost productivity by government workers in Washington, D. C. SMSA area due to eye irritation.

Table 19 shows total civilian U. S. employment, civilian employment and payroll in Washington, D. C. SMSA, and cost of a 10 percent reduction in productivity for 88 hours per year. The 1970 value is based on 6 percent interest compounded to 1970.

Table 19. Eye Irritation - Loss in Productivity

Value of a 10 percent reduction in productivity of Federal employees for 88 hours[a] per year in SMSA - Washington, D. C.[b]

Year	TOTAL U.S. (000,000)	Washington, D.C. SMSA No. (000,000)	Washington, D.C. SMSA Payroll (000,000)	Productivity Loss[c] (000,000)	Compound Interest	1970 Value [illegible]
1960	2.43	.24	1,286	5.44	1.79	9.74
1961	2.44	.24	1,401	5.93	1.69	10.02
1962	2.50	.26	1,519	6.43	1.59	10.22
1963	2.52	.26	1,661	7.03	1.50	10.55
1964	2.51	.26*	1,793	7.58	1.42	10.76
1965	2.54	.28	1,947	8.24	1.34	11.04
1966	2.75	.30	2,157	9.13	1.26	11.50
1967	2.96	.31	2,266	9.59	1.19	11.41
1968	2.98	.31	2,499	10.57	1.12	11.84
			TOTAL	69.93		97.08

*Estimate

Source: (a) Larsen, R. I., Proceeds from Air Quality Criteria to Air Quality Standards and Emission Standards - APCA Paper 69-210[25].
In Washington, D.C., measured oxidant levels in ambient air at the CAMP stations have been above eye irritation threshold for an average of 88 hours per year: If productivity is reduced by 10 percent as a result of the high oxidant levels then the government loses 10 percent of the payroll during high oxidant periods. These occur during the day and working days when auto traffic is high.

$$\frac{(88)\ (.1)}{2080} \times \text{payroll} = \text{loss to government}$$

2080 = number of working hours per year.

(b) Statistical abstracts.

(c) Cost of a 10 percent reduction in productivity for 88 hours Washington, D.C., SMSA per year (million dollars)

** *No known source - The 10 percent loss in production is not based on research findings-* speculation only. Eye irritation from smog is a nuisance and results in some loss of production. The 10 percent figure seems reasonable as an approximation.

There is no research results available on reduction in productivity. I telephoned the Los Angeles Air Pollution Control Board and the Los Angeles County AMA to see if they knew of research or information on effects of smog and eye irritation. I failed to get any information from them. Eye irritation is a nuisance and it has a definite effect. The reduction of 10 percent was selected as a reasonable estimate and to show how this counts up when applied to all governmental employment.

The hours per year of eye irritation smog is based on measurements made at the CAMP station in Washington, D. C.

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ENVIRONMENTAL PROTECTION AGENCY
Air Pollution Control Office
5600 Fishers Lane, Rockville, Maryland 20852

Date:

Reply to Attn of:

Subject: Review of p blic papers to document the delay of pollution control technology by the automobile industry

To: Dr. Hyman Ritchin
Justice Department

As you requested, I have reviewed the technical literature and the available public issuances of the California Motor Vehicle Pollution Control Board. In this memo I have pulled together items which I believe relevant to your case. It should be noted that although the technical literature was thoroughly surveyed there are two sources which were not explored. These are the records of the Los Angeles County air pollution control program and the California Motor Vehicle Pollution Control Board. These two sources, I am sure, would yield much additional documentation of value to your case. If you feel such additional information necessary I recommend these sources also be explored. I have organized this report in a chronological fashion to convey the historical development (or non-development) of the technology.

* * *

The industry often points to 1952 as the beginning of their work on the control of vehicle emissions. The implication being that at that point in time they began their research without any previous knowledge of exhaust emis ions and thus progress should be expected to have occurred very slowly. But a review of the technical literature shows that by 1952 substantial research on exhaust composition had already

been done. (1,2,3,) When Dr. Haagen-Smit irrefutably identified auto exhaust as a cause of photochemical smog in 1952 there already existed a body of knowledge on the techniques of exhaust gas measurement and some of the parameters influencing exhaust gas composition.

In a moment of candor, GM's technical director, John Campbell related:

> "GM has been cognizant of the exhaust gas problem for many years and the research laboratories of GM have been responsible for the discovery of much of the basic information on exhaust gas that is available today on this subject.
>
> "Carbon monoxide has generally been considered the principal component of exhaust gas that is injurious to health. Through improvements in carburetion, ignition, and engine design, we have reduced the average carbon monoxide content of exhaust gases by a very significant amount over the past 20 years."(4)

Interestingly the parameters of carburetion, ignition, and engine design were the very parameters that were to be varied fifteen (15) years later to meet the 1968 Federal emission standards. Thus the proposition often put forth by the industry that in 1952 the industry knew nothing about emissions is misleading and self-serving.

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[1]D'Alleva, B. A. and Lovell, W. G., "Relation of Exhaust Gas Composition to Air-Fuel Ratio," S.A.E. Journal 38(3), 90-98, 116 (1936).

> Complete exhaust gas analyses for CO_2, CO, hydrogen, methane, and oxygen have been related to directly measured air-fuel ratios for three engines over a range of operating conditions and with varied air-measuring equipment.

[2]Fieldner, A. C., and Jones, G. W., "Sampling and Analysis of Automobile Exhaust Gas," Franklin Institute Journal, Vol. 194, pp. 513-644 (November 1922).

[3]Magill, P. D., Hutchinson, D. H., and Stormes, J. M., "Hydrocarbon Constituents of Automobile Exhaust Gases," Proc. Natl. Air Pollution Symposium, 2nd Symposium, Pasadena, California, 1952, pp. 71-83.

[4]Letter to Mr. Kenneth Hahn, Los Angeles County Supervisor from Mr. John M. Campbell, Administrative Director, Engineering Staff, GM dated March 26, 1953.

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Deceleration Devices - Developed but not deployed

In this same letter, Mr. Campbell wrote the following:

> "Finally, it might be said that our organization and others are continually seeking a practical solution to every one of the problems which you have enumerated and just as fast as practical solutions, even partial ones, are found they will be put into commercial use because of the continual competitive incentive toward making engineering improvements in the automotive industry." (Emphasis added).

Would that the industry had kept that promise. But five years later, history finds Mr. Hahn still imploring the industry on behalf of the people of Los Angeles. His letter to Mr. Curtice, President of General Motors (a similar letter sent to each auto company) dated July 16, 1957, begins:

> "I would sincerely appreciate it if you would let me know if General Motors Corp. is planning to install on its 1958 model automobiles a device (either a new type muffler or engine device) which will eliminate or help reduce the air pollution problem of Los Angeles County."

The reply of Mr. Chandler of Ford dated July 24, 1957, is informative:

> "Referring to the application of devices to production automobiles, I might emphasize that the industry has worked intensively on induction-system devices for reducing hydrocarbon emission during deceleration and has, in fact, supplied the Los Angeles Air Pollution Control District with preliminary working models of these devices for evaluation by the district. Further work in Detroit since these devices were submitted has resulted in making the devices more acceptable from a driving standpoint, and these improved devices are also being made available to the air pollution control district at their earliest convenience.
>
> "As we have stated in our earlier letters, it is quite important that any device which we submit be very carefully evaluated by your air pollution control district so that any possible benefit to be derived from such a device can be clearly determined. The automobile industry has accepted the responsibility for reducing

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> hydrocarbon emission from automobile exhaust to the best of its ability. It is, however, up to your local authorities to determine whether or not such a reduction will result in any reduction in the smog problem. It is thus essential that the evaluation of the devices be most carefully and thoroughly made so that a decision will not be reached which might result in unnecessary expenditures by the people in Los Angeles."

Paraphrasing, Ford's reply might read:

> We've made some progress but if you (county officials) want the people of Los Angeles to benefit from it you will have to make the difficult political decision that this small improvement in emissions is worth the substantial costs associated with it.

This challenge proved to be too much for the County. Their competent but small technical staff could not match the industry in doing independent research. The technical staff could only provide an evaluation of the systems supplied by the industry. Thus it is not surprising that their findings were insufficient to permit the adoption of a strong position by the Board of Supervisors. The County's technical staff reported "...Under road conditions, on deceleration cycle only, fuel shutoffs have shown hydrocarbon reductions in the 50 to 60 per cent range."[5] Try as they might the small staff could not out do the industry.

In March of 1958, Mr. Hahn writes, perhaps a bit testily:

> "I am fully acquainted with, and appreciate, the work which the automobile industry has done, and is doing, in researching this problem, but the health and welfare of the nearly six million people in this area demands more effective results.

[5]Linville, W., Holmes, R. G., Kanter, C. V., Evaluation of Methods for Controlling Vehicular Exhausts, APCA Annual Meeting, Los Angeles, California, June 1959.

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> **"I believe that by conducting a public hearing and establishing a deadline date by which the automobile industry must come up with a satisfactory device in order to sell new cars here, that the Board of Supervisors will be performing a service for you in providing a definite time goal, and that this will make our position and intentions clear to the people."**

The industry replies. Ford, April 9, 1958:

> "I am sure that you are also aware of the fact that the automotive industry has submitted deceleration devices to your air pollution control district. You also must realize that we now know that these devices will reduce total hydrocarbon emission from automobile exhaust by no more than 25 per cent. The apparent conclusion of your air pollution control district that the cost of applying, inspecting and maintaining these devices would not be justified by such a low rate of reduction seems reasonable."

GM, April 15, 1958:

> "The fact is that the solution to this problem has turned out to be a much more difficult one than was originally supposed by most people. Although we now have a much better understanding of the problem, we do not as yet have a practical solution in sight. Our efforts to find relief in some form of carburetor modification have <u>not proven sufficiently effective to warrant recommended use</u>. Our present efforts are directed toward an exhaust burner, either catalytic or open flame, but while we have had some promise of success in our experiments, we have not yet produced a commercially acceptable sample that could even be considered for use by the public. There are a number of problems such as noise, space limitations, warm-up time, safety from fire hazards and objectionable odors that have not yet been solved. (Emphasis added).

The story of deceleration devices ends. Would that in 1958 GM had kept their promise that "even partial solutions would put into use just as fast as they are found. . .because of the continual competitive incentive." Had they kept that promise on cars manufactured after 1958 by now that 25% reduction would have prevented the emission of millions of tons of hydrocarbons. The failure to utilize deceleration devices continues

to cause excessive emissions even now in the 1970's. The millions of uncontrolled pre-1968 vehicles continue to excessively pollute the air. Apparently between the 1953 and 1958 letters, the continual competitive incentive had disappeared because the promise was not kept. And the public had to wait another 10 years before induction device technology would be applied.

Unclear Statements Put Industry in the Clear

Statements by the AMA appear to be very carefully worded. But sometimes these statements have a tendency to mislead public representatives not aware of the technical literature. For example, on November 14, 1960, Ralph H. Isbrandt, Chairman, AMA Engineering Advisory Committee and Director of Automotive Engineering and Research at American Motors Corp. reported to the California Motor Vehicle Pollution Control Board (Dr. Middleton was Chairman):

> "Assisted by the development of new instrumentation and more effective techniques for the analysis of exhaust gas emissions, one of the company teams learned, in the Fall of 1959, that crankcase blowby was an important source of unburned hydrocarbons. (Emphasis added).
>
> "The device has many virtues, including simplicity, low first cost, long service life, and ease of inspection to determine whether or not it is operating properly. This device is not, however, simple in the sense that little or no engineering is required for its development and adaptation."

And in the "AMA Memorandum on the Department of Justice Investigation"[6] one reads:

[6]Often referred to as the "green book."

"In 1959 through a truly extraordinary stroke of good fortune--the crankcase was discovered to be a more important source of emissions than had been suggested by prior government and other studies."

In a review of the technical literature, however, one finds in the proceedings of the 2nd National Air Pollution Symposium dated May 1952 that the industry's attention was drawn to blowby as an important source of noxious emissions nearly a decade earlier.[7]

"The rates of blowby relative to exhaust are quite low, however, the higher concentrations of noxious products make blowby a factor to be considered in regard to air pollution. The effect to deteriorating engine condition is to increase blowby and, consequently, to increase the total amount of noxious products. This change may be greater than tenfold at low speeds typical of city driving."

"Of the products identified as definitely or probably present in blowby, aldehydes and acids have characteristic irritating effects on the nose, eyes, or both. Combinations of these with other exhaust and blowby products or with other air pollutants may accentuate these effects. Organic hydroperoxides identified as probably present have been blamed in past theories as being serious contributors to air pollution."

Eight and one-half years later, on October 18, 1960, GM's president was gratified to report but only to those U. S. citizens residing in California:[8]

"I am gratified to be able to report that positive crankcase ventilation is available on all 1961 General Motors passenger cars being delivered to California. We believe that this relatively uncomplicated, inexpensive device will perform a major job of reducing air pollution.

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[7]Payne, J. O. and Sigworth, H. W., "The Composition and Nature of Blowby and Exhaust Gases from Passenger Car Engines," Proceedings National Air Pollution Symposium, 2nd Symposium, Pasadena, California 1952, pp. 62-70.

[8]Letter dated October 18, 1960, from John F. Gordon, President of General Motors to Mr. Kenneth Hahn, Los Angeles County Supervisor.

> "As you know, the automobile industry is collectively working on the problem. The voluntary offering of these devices by the entire automobile industry to the new car buyers of California, I believe, is concrete evidence of the sincerity of our efforts."

Auto industry executives often boast of their voluntary contributions to pollution control technology. And one would like to believe in the sincerity of their efforts as Mr. Gordon asked.

But many of those in government who have been fighting for clean air do not believe that much has been done voluntarily. What is believed is that the efforts of the County of Los Angeles in 1958 and 1959 to secure legislation to establish a state-wide motor vehicle pollution control program provided the motivation for the industry to break through the technological barrier and "voluntarily" install the PCV valve on California cars. It is believed that the threat of regulatory authority did more to bring about the breakthrough than did "a truly extraordinary stroke of good fortune."

The AMA's account of history to the Justice Department which follows, leaves out some critical details and again tends to mislead those unfamiliar with the technical literature.

> "In 1959--through a truly extraordinary stroke of good fortune--the crankcase was discovered to be a more important source of emissions than had been suggested by prior government and other studies. Adaptation of positive crankcase ventilation to the cars of all the companies followed immediately, with the result that all 1961 model vehicles sold in California, beginning in the Fall of 1960, had as standard equipment a system of positive crankcase ventilation adapted to the technical needs of each manufacturer's engines. Notwithstanding serious engineering reservations about the technique and practically no customer demand, positive crankcase ventilation was installed by the manufacturers on all vehicles sold by them in the United States beginning in the Fall of 1962."

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The AMA in their reference to "serious engineering reservations about the technique" were apparently trying to mislead the Justice Department's non-technical attorneys. But in the Air Pollution Control Office's copy of the green book, Assistant Commissioner William H. Megonnell, penciled in "Hogwash! They'd been in use for 30 years."

Another important fact conveniently omitted is that in 1961 then Secretary of HEW, Abraham Ribicoff offered the automobile industry the "choice" of "voluntary" installation of PCV valves on all U. S. cars or he would seek legislation to require such installation by Federal regulation. Congressman Fogarty of the House Appropriations Committee added his support to the Secretary as follows:[9]

> "I cannot escape the conclusion that the automobile industry has been dragging its feet in the matter of factory installation of blowby devices. These, as you probably know, are relatively inexpensive devices for controlling emissions from automobile crankcases. While they will not solve the larger problem of exhaust emissions from the tailpipe, they do eliminate from one-fourth to one-third of the motorcar's total contribution to our air pollution problem.
>
> "Such devices were factory-installed on new cars sold this year in the one State of California and are available--at a higher price, of course--as optional dealer-installed equipment on new American cars in other localities. In view of the mounting evidence that air pollution not only is costly but may also be highly hazardous to human health--and since this new device eliminates a part of it at a low cost--it would have seemed both good business and good public relations for the auto industry to install such a device at the factory on all new cars sold in this country. This in fact is what Secretary Ribicoff recently recommended....

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[9]Congressman Fogarty, Congressional Record, May 17, 1961, pp. 7689 and 7690.

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> "I should think that these two rich industries (oil and auto)--simply in enlightened self-interest, if for no other reason--would do everything they reasonably could do to abate their own contribution to this growing environmental hazard, if only to avert the risk of drastic legislation which might seem to them much less reasonable in its demands. Many of the controls imposed on the refineries in Los Angeles also make economic good sense, too, in that they cut down losses from evaporation of a marketable product. Any factory-installed blowby devices for automobiles cost less than $5 and also improve the car's function.
>
> "What could be more reasonable than for both the oil and automobile industries to follow throughout the country the splendid example set in Los Angeles?"

The Discovery of Exhaust Emission Controls

In 1957 when the competitive incentive apparently was missing, the AMA Induction System Task Group[10] reported to the technical community at an SAE meeting their findings after two years of evaluation of various systems. An idea of how limited a mandate management gave these engineers might be gleaned from the following statements:

> This group studies the available information on hydrocarbon emission. Experience of the members on engines and carburetion was utilized. It did not appear that appreciable reductions in the idle, acceleration and cruise phases of operation could be made by readily applicable design changes. (Emphasis added).

With the limited mandate reflected in this brief charter description one can understand the adoption of the following limited goal:

> One of the first acts of the Induction System Task Group was to decide on its goals. These evolved from discussion during the first few meetings and were recorded as follows:
>
> 1. Only devices for control of hydrocarbons during deceleration would be studied (Emphasis added).

Yet further on in this 1957 paper, Dietrich gives us a glimpse of the pollution control systems to be placed on 1968 automobiles.

[10] Dietrich, H. H., "Automotive Exhaust Hydrocarbon Reduction During Deceleration by Induction System Devices," SAE 170, Aug. 1957.

> **The idle adjustment. As seen in Figure 3, a lean idle adjustment produces considerable less hydrocarbon emission during deceleration than a rich-idle adjustment.**

And just as revealingly but in negative terms the second aspect of the 1968 systems is described:

> "<u>Device to Change Ignition Advance During Vehicle Deceleration</u>--Optimum spark advance during deceleration (about 30 deg btdc) produced slight reductions in hydrocarbon emission on a vehicle during road test, but the improvement was not significant enough to warrant the necessary complication."

One might ask: Significant enough to whom?

In 1962, Mr. Charles Heinen of Chrysler tells the technical community of the engine modification kits developed by Chrysler.[11] He describes these kits as consisting of:

a. Altered choke setting--to lean out mixture sooner.

b. Lean-idle adjustment

c. Lean carburetor jets

d. Retarded spark timing at idle

e. A vacuum advance control valve--to advance spark timing on deceleration.

Chrysler's Mr. Heinen goes on to describe the results of tests conducted in 21 laboratories on 58 vehicles equipped with these kits.

> "With but one exception all vehicles on which we have received reports met the California Standards for hydrocarbons after the kits had been properly installed. All met the Standards for carbon monoxide. It should be noted that some laboratories reported hot cycles only. The mileage on the cars used ranged from new to approximately 30,000 miles. The vehicle that did not meet the standard showed 291 ppm HC on the full California cycle. The difficulty appeared to lie in the warm-up cycle...."

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[11] Heinen, C. M., "Using the Engine for Exhaust Control," S.A.E. S 355, November 1962.

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"Where increases occurred, the vehicles could be returned to normal by an adjustment of the idle screw to the proper carbon monoxide content, a change in the idle rpm to the recommended value, a timing adjustment, or a combination of the three...."

"In summary, it appears at this stage that the modifications and adjustments represented by the "kits" are capable of lowering exhaust emissions of 318 cu. in. Chrysler engines to levels below the California Standard. The only point in question would appear to be what frequency of adjustments is necessary to keep them there for 12,000 miles."

The public might have hoped that Mr. Heinen would have continued to announce the installation of these systems on all 1964 model year vehicles. Unfortunately he did not. Instead the public had to wait until three (3) years later, when in 1965, the Chrysler Corporation's Vice President, B. W. Bogan, testified before the Senate Subcommittee that the system would be on 1966 model year California cars. And that given two more years lead-time, and barring any unforeseen problems, and:

"if necessary, we should be able to start our production tooling program to supply those cold weather areas (of the U. S.) which feel that they have an air pollution problem of the type encountered in California. Thank you." (Emphasis added).

The public would have to wait until the industry was told it was indeed necessary. First the Congress would have to authorize the Federal Government to set national emission standards, then the Federal Government would have to adopt the California emission standards, and then given sufficient lead time of two years, the industry would begin the nationwide installation of exhaust emission controls with the 1968 model year. A system evaluated and reported on in 1957, and developed by 1962 was placed on all new vehicles in 1968.

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The Temporary Restoration of Competition

In 1959 the California legislature expressing frustration over the lack of progress in motor vehicle pollution control passed a law requiring the State Department of Public Health to set air quality standards and motor vehicle exhaust emission standards. That same year, 1959, California set exhaust emission standards of 275 ppm hydrocarbons and 1.5% carbon monoxide. These emission standards were aimed at restoring the degree of air quality which existed in Los Angeles in 1940. By 1970!

That this action by the California legislature was in vain can be seen from the following figures:

Estimated Emissions from Motor Vehicles in Tons Per Day - Los Angeles[12]

	1940	1959	1970
Carbon Monoxide	2,500	8,500	8,500
Hydrocarbons	600	1,800	1,500
Oxides of Nitrogen	125	390	730

The California law specified that the emission standards would apply upon State approval of two emission control systems which demonstrated the ability to meet the standards. It required that all cars sold in

[12]Profile of Air Pollution Control in Los Angeles County," L. A. County Air Pollution Control District, 1969.

California would have to be equipped with an approved system.[13] Since the Californians were buying automobiles at the rate of nearly a million cars per year, the law provided a potential market and thereby a financial incentive to private developers. Thus, in 1959 the auto industry was given an external competitive incentive to compensate for the intra-industry competitive incentive which had apparently been lost after 1953.

The California law provided an incentive for the "discovery" of control systems.

In November 1962 when Mr. Heinen reported on the Chrysler Kit the industry was feeling some of the pressures of competition building. In July of 1963 when Chrysler became the first major manufacturer to apply for California approval, the state Motor Vehicle Pollution Control Board already had under test seven independently designed exhaust control systems.

In June 1964, the California Motor Vehicle Pollution Control Board met to consider official approval of four independently manufactured exhaust control devices. Official approval of just two systems would trigger the standards and all new vehicles would have to be equipped with one of the systems. At the meeting, Virgil Anderson, representing

[13] Clarkson, D. and Middleton, J. T., "The California Control Program for Motor Vehicle Created Air Pollution." Air Pollution Control Association, June 11, 1961, New York City.

the California State Automobile Association asked the Board to delay the effective date of certification so that exhaust controls would first appear on 1967 model cars (instead of 1966) in accordance with the promise of the automobile manufacturers. Mr. Anderson was followed by Mr. George Delaney, representing the Automobile Manufacturers Association. He emphasized that the auto companies had the same sense of urgency as the Board with respect to getting exhaust controls on new cars. But the industry felt that the 1967 model year was the first time systems could be on cars which would meet Detroit's standards for performance, durability, and customer satisfaction.[14]

The Board disregarded these pleas for delay and granted approval to the following systems:

1. American Machine & Foundry - Chromalloy
2. Arvin - Universal Oil Products
3. W. R. Grace - Norris Thermador
4. Walker Manufacturing - American Cyanamid

These approvals triggered the law and required all 1966 model year vehicles to be equipped with one of the approved systems.

Less than eight weeks later on August 12, 1964, a major breakthrough was announced by the four major automobile manufacturers. The industry would have their own control systems meeting California standards on 1966 model cars to be sold in California.

[14] Motor Vehicle Pollution Control Board Bulletin, June 1964.

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Thus the people of California could breathe a sigh of relief for a long hard fought battle (but not the war) was won. But the automobile industry also was able to breathe a sigh of relief because the compelling competitive incentive which had arisen was once again removed.

Louis V. Lombardo
Technical Assistant
Mobile Source Pollution Control Program

APPENDIX

In reviewing the technical literature, one could not help being struck by the irregularity in the number of technical papers presented each year. Normally over a period of 15 years of increasing research and development one would observe a pattern of relatively steady growth in the number of papers published each year. In the field of motor vehicle pollution control, however, in lieu of a pattern of steady growth in the number of papers published each year, we find an unusual and highly irregular pattern. We find from the tabulation below that over the period 1955 through 1966, only four years were notable by the number and quality of the publications: 1955, 1957, 1962, 1966.

Year	Number of SAE Papers Published	Comments
1955	8	Papers describe emissions, their measurement and causes.
1956	1	
1957	10	Deceleration devices described
1958	4	
1959	6	
1960	4	
1961	1	
1962	21	PCV described
1963	7	
1964	5	
1965	7	
1966	24	1966 exhaust control systems described

It is difficult to avoid the impression that the release of these papers was controlled. Surely an unhampered publication process would have demonstrated a more normal exponential growth pattern.

[From the Congressional Record—House, May 18, 1971]

SMOG CONTROL ANTITRUST CASE

(Mr. Burton asked and was given permission to address the House for 1 minute, to revise and extend his remarks and include extraneous matter.)

Mr. BURTON. Mr. Speaker, on September 13, 1969—see Congressional Record for that date—I joined with 17 of my colleagues in urging an open trial in the smog control antitrust case.

Just this week I have received a document which I am offering today for my colleagues to examine, a document presented to me by reliable persons, and which is described as a confidential memorandum of the U.S. Department of Justice. This memorandum recommended to the Attorney General that criminal charges be brought against American auto manufacturers for conspiring to retard the development of a smog-free motor vehicle.

This memorandum, which spells out in detail previously undisclosed evidence, was prepared before January 10, 1969, when the Department of Justice decided to proceed with a civil suit. Subsequently, the Department of Justice agreed to settle the matter with a consent decree.

These disclosures are especially painful in light of the settlement of the Government's civil case in September 1969 which was filed in lieu of any criminal case. This settlement by a consent decree increased the legal burdens for later litigants, failed to provide for any restitution of damage done, failed to contain adequate reporting requirements, and failed to prohibit the destruction of past documents—all in tradition of ex parte negotiations which form the cornerstone of the consent decree program.

I release this document today because I agree with the metaphor principle behind Louis Brandeis' statement that "sunlight is the best of all disinfectants." Public exposure of these formerly secret materials can only serve to educate the people as to the industry's capability for a major health problm. The consent decree settlement deprived the public of an open trial on all the issues. An open trial would educate the unreformed and deter the potential violator, especially in the auto industry which has for too long been dealt with by gentlemanly trustbusters in the shadow of Government. Sunlight will do it well.

The material follows:

PROPOSED DEFENDANTS AND CO-CONSPIRATORS

PROPOSED DEFENDANTS

Corporation and State of incorporation

AutomobileManufacturers Association, Inc., New York.
General Motors Corporation, Delaware.
Ford Motor Company, Delaware.
Chrysler Corporation, Delaware.
American Motors Corporation, Maryland.

The entire conspiracy was organized and nurtured in and operated through the Automobile Manufacturers Association (AMA), the trade association of the automobile industry with a membership of nearly 99% of all domestic car and truck manufacturers. The Board of Directors of AMA made all policy decisions in the motor vehicle air pollution control field and the members adopted those policies. AMA is, therefore, proposed to be named as a defendant.

The big four of the industry—General Motors, Ford, Chrysler, and American Motors—were most active in the conspiracy primarily because they were most affected financially if required to install pollution control devices on the millions of cars they manufactured annually, amounting to a vast majority of all domestic car production. General Motors, Ford, Chrysler, and American Motors are, therefore, proposed as defendants.

The conspiracy, which started at least as early as 1955, has lasted so long that many of the participants have abandoned their participation by severing connection with the employers they represented by retirement or otherwise. Too, so many people were involved on behalf of the companies involved that it would be unrealistic to name them all as defendants. The following representative officials who were active in the conspiracy were selected, therefore, as proposed defendants:

PROPOSED CO-CONSPIRATORS

Corporations and State of incorporation

Checker Motor Corporation (successor to Checker Cab Manufacturing Corporation), New Jersey.

Diamond T Motor Car Company, Illinois.

International Harvester Company (a consolidation of International Harvester Company, a New Jersey corporation, and International Harvester Corporation, a Delaware corporation), Delaware.

Studebaker Corporation (successor to Studebaker-Packard Corporation), Michigan.

White Motor Corporation (successor to The White Motor Company), Ohio.

Kaiser Jeep Corporation (successor to Willys Motors, Inc., a Pennsylvania Corporation), Nevada.

Mack Trucks, Inc. (successor to Mack Manufacturing Corporation), New York.

INDIVIDUALS PROPOSED AS CO-CONSPIRATORS

All members of the Board of Directors of AMA from January 1, 1953 to the date of the indictment, other than those named as defendants hereto.

All members of the Engineering Advisory Committee of AMA from January 1, 1953 to the date of the indictment, other than those named as defendants herein.

All members of the Vehicle Combustion Products Committee of AMA from December 4, 1953 to the date of the indictment, other than those named as defendants herein.

All members of all Task Groups which were subcommittees of the Vehicle Combustion Products Committee from December 4, 1953 to the date of the indictment.

All members of the Patent Committee from January 1, 1953 to the date of the indictment.

———, employed by AMA, acted as its liaison officer between it and its members in the air pollution control equipment field and also as its representative before state, county, and local boards and agencies concerned with motor vehicle air pollution control.

The foregoing corporations are all AMA members and signatories to the cross-licensing agreement, the vehicle about which the conspiracy revolved. They are, therefore, proposed as co-conspirators.

The other proposed co-conspirators are the many participants in the conspiracy.

BACKGROUND

Air pollution is a national problem. Polluting, emissions from automobiles is one of the causes. Because of the topography [1] of Los Angeles, California and the high concentration [2] of automobiles in that area, the problem was first recognized by the country and then California state officials, and efforts to compel remedies were first imposed there. This memorandum relates to collusive activities of the automobile manufacturers in connection with research, development, manufacture, and installation of motor vehicle air pollution control devices. As background, the Los Angeles story is important.

The word "smog," derived from abbreviations of smoke and fog, is a misnomer. What is commonly called "smog" is really the result of chemical reactions that take place in polluted air, heated by the sun's rays, and is evidenced by one or more effects much as eye irritation, reduced visibility, high ozone concentration, plant damage, and odor, It is recognizable by a "brownish" or "bluish" haze which many times obscures the surrounding mountains.

The air pollution control program was commenced by the State of California in 1947. In early 1951, Dr. Arie J. Haagen-Smit, a renowned research chemist at the California Institute of Technology, discovered that when oxides of nitrogen, ozone and gasoline (hydrocarbon) vapors were introduced into a plexiglass test chamber and exposed to ultra violet light (artificial sunlight), an irritating haze with all the properties of natural smog was formed. It was this research that pinpointed the motor vehicle as one of the major sources of air pollution and became known as the Haagen-Smit or hydrocarbon theory of smog formation.

Footnotes at end of article.

Following the publication and general acceptance of the Haagen-Smit theory, the automobile industry finally acknowledged that motor vehicles contributed to air pollution, which it had steadfastly denied prior thereto. The problem of how to control motor vehicle emissions was then turned over by the industry to the Automobile Manufacturers Association (AMA), of which all the automobile manufacturers were and are members.

From the very outset the industry realized that air pollution control devices do not help sell automobiles. (Tr. Vol. XXXVIII, p. 11; Tr. Vol. LVIII, p. 170).

In his testimony (Tr. Vol. XXXV, pp. 32–33), Supervisor Hahn of Los Angeles County confirmed the following statement appearing in Ralph Nader's book, "Unsafe at Any Speed" at page 100:

"When Mr. Hahn went to Detroit to get some direct answers about adoption of exhaust controls, a senior official of one of the companies asked: 'Well, Mr. Hahn, will that device sell more cars?' 'No,' said Mr. Hahn. 'Will it look prettier, will it give us more horsepower? If not, we are not interested.' "

A letter of November 17, 1938 from Lloyd Withrow, head of the Fuels and Lubricants Department of General Motors (GM), directed to Dr. L. R. Hafsted of that company, states in part: "financing this work is most expensive, and the incentives for carrying it out are closely related to political consideration." The letter goes on to state that "[t]he development of exhaust control devices cannot be justified on a business basis; the only hope of a return on such an investment is possible legislation requiring their use." After pointing out that none of the devices contribute appreciably to the efficiency performance, or appearance of the automobile, the letter concludes that on account of the reasons advanced, "the managements of Corporation Divisions are reluctant to undertake the engineering and development of devices, even though they appear to be based on sound principle." (Tr. Vol. XXXVII, pp. 101–105; GJ Ex. 525).

While the general public talks a lot about air pollution, most people prefer doing without control devices rather than to pay for them. As a result the industry engaged in lip service concerning the health and welfare of the community and the necessity for prompt research, development, and installation of motor vehicle air pollution control devices. In fact, as hereinafter shown, the automobile manufacturers, through AMA, conspired not to compete in research, development, manufacture, and installation of control devices, and collectively did all in their power to delay such research, development, manufacturing, and installation.[3] Indicative of this industry attitude is the very firm position taken in regard to the California authorities, as reported by Dr. J. D. Ullman of E. I. Du Pont after a visit to Detroit in January, 1960.

"Basically, the automotive manufacturers would seek to avoid installing a reactor of any sort on a car because it adds cost, but provides no customer benefits such as improved engine performance or styling advances. From this thinking [the following fact, among others, evolves]:

"(1) A smog abatement device will be installed on cars for California market only after being approved and requested by the Government of California. The industry has told California that cars will be equipped with devices designated by California one year from the date of designation." (GJ Ex. 194).

Also, failure on the part of the manufacturers to purchase devices of independent companies, produced at costs of millions of dollars, discouraged such independents from further research, development, or manufacture of control devices to the great detriment of the American people, science and industry.

An AMA internal memorandum prepared for presentation at Vehicle Combustion Products Committee (VCP) and Engineering and Advisory Committee (EAC) meetings disclosed that as recently as January 15, 1965 the same dilatory considerations prevailed:

"On the basis of the facts the industry is not convinced that exhaust emissions devices or systems are necessary for nationwide application to motor vehicles but believes instead that they will be an economic and maintenance burden on motorists. It is, therefore, not prepared to desirous to intiate any voluntary program to impose these systems or devices on all customers nationwide, or to accept the responsibility for such a decision, in the face of a lack of convincing evidence." (GJ Ex. 411).

The seriousness of the basic problem of air pollution in Los Angeles is highlighted by the following statistics: As late as January 1967, even with the installation of air pollution control devices compelled by law, 12,465 tons out of a

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Footnotes at end of article.

total of 14,001 tons per day of contaminants within Los Angeles County are caused by gasoline powered motor vehicles, or in other words, 85.3% of all contaminants in the area are still caused by motor vehicles. (GJ Ex. 486).

THE AUTOMOBILE MANUFACTURERS ASSOCIATION

The AMA is a trade association whose members manufacture 99% of the cars, trucks, and buses produced annually in the United States. Tr. Vol. XX, p. 52; Tr. Vol. XXI, p. 124; GJ Ex. 394). The policies of AMA are made by and the activities of AMA are carried on under the direction of its Board of Directors, (Tr. Vol. XX, p. 50). The Board of Directors is comprised of the President and Chairman of the Board of the automobile and truck companies who are members of the Association. (Tr. Vol. XVII, p. 5). Until recently [4] the President of AMA was chosen from among the members of the Board of Directors. (GJ Ex. 255 and 300).

Most of the work of AMA is done by committees. (Tr. Vol. XVII, p. 6). When the air pollution control program was commenced, the VCP, a subcommittee of the EAC (which consists of the Vice-Presidents in charge of the engineering department of each member company), was established by the AMA. (Tr. Vol. I, pp. 88–90, GJ Ex. 260; Tr. Vol. XXXXVII, pp. 52–56, GJ Ex. 565). Membership in the VCP consists of project engineers of the various member companies. (Tr. Vol. XXXXV, p. 32). The following excerpts from documents and testimony illustrate the broad scope of the assigned VCP responsibilities:

The Vehicle Combustion Products Committee of the Automobile Manufacturers Association which has been assigned the responsibility for the past four and one-half years of conducting an intensive cooperative program dealing with all aspects of the automobile exhaust problem . . . (GJ Ex. 258, excerpt from draft, dated March 10, 1958, prepared for presentation to House Safety Committee).

"As the role of the automobile in smog formation was being disclosed, the AMA Board of Directors, in 1954, instructed industry engineers to look into the situation immediately and make recommendations for industry action.

"INDUSTRY ACTION

"As a result of this investigation, the AMA Board decided that the problem should be dealt with on an industry team basis. Accordingly, it formed the Vehicle Combustion Products Committee to direct all industry efforts on a noncompetitive basis." (Tr. Vol. XXXXVI, pp. 52–54; GJ Ex. 565).

Mr. Robert T. Van Derveer, director of Motor Vehicle Components Laboratory, United States Department of Health, Education and Welfare, formerly head of the Fuels and Exhaust Emissions Department, American Motors Corporation (American), testified that this noncompetitive industry-wide approach concerned not only research and development, but also the installation and marketing of devices; that is, that all aspects of company activity in this field were to be coordinated through the AMA (Tr. Vol. XXXXVI, pp. 53–55).

A number of task groups report and make recommendations to the VCP on specific areas of the automobile which affects emission; e.g., the Crankcase Ventilation Task Group, the Exhaust System Task Group, and the Fuel System Emission Task Group. (Tr. Vol. XVII, pp. 8–10).

The VCP in turn reports and makes recommendations to the EAC. (Tr. Vol. XVII, p. 6). The following except from GJ Exhibit 335, (Tr. Vol. XX, p. 56, 61–62) sheds light on the role and composition of the EAC:

"The industry cooperative program is directed by the AMA Board of Directors but is under the technical control of our Engineering Advisory Committee whose chairman, Herb Misch, of Ford Motor Company, will preside this noon. Mr. Misch and all of the other members of the Engineering Advisory Committee are vice presidents in charge of engineering of their companies and are therefore in an excellent position to direct the technical activities which are carried on by the Vehicle Combustion Products Committee and its various working groups and panels."

The EAC in its turn reports and makes recommendations to the Board of AMA. (Tr. Vol. XX, p. 62). It is, however, the Board of Directors which makes all of the policy decisions of AMA. (Tr. Vol. XX, pp. 59, 62; Tr. Vol. XXXXVI, p. 4).

Footnotes at end of article.

THE CONSPIRACY

As early as 1955 and even prior thereto, public speeches and statements made by the top brass of the leading automobile companies heralded the fact that cooperative effort was being undertaken in the automobile industry in order to accomplish a solution to the motor vehicle air pollution control problem as expeditiously as possible.

In a speech made on April 18, 1955, James C. Zeder, then Vice President of the Chrysler Corporation (Chrysler), said:

"Perhaps you are somewhat surprised to find that we are acting cooperatively in the battle against 'smog.' Our industry has a reputation for being fiercely competitive, and we're proud of it. Ordinarily, competition in research and engineering, as well as in production and sales, can be proved to be the best way to get maximum results and progress. The automobile industry and business has been demonstrating this for more than 50 years. But it has also demonstrated that under some conditions, where the public interest is primarily involved, it is possible to get to a solution of a problem quicker by sharing knowledge and by helping each other bear the work load. At such times we cooperate as energetically as at other times we compete." (GJ Ex. 326).

Similarly, in the language of Charles A. Chayne, then Vice President of General Motors and Chairman of the EAC in 1954:

"Before I go further, therefore, let me pause to add my personal salute to the civic spirit that launched the cooperative program, 'Operation Teamwork' which went into effect last August. It is the kind of teamwork which we have adopted in the automotive industry on a number of historic occasions when it was obviously more beneficial to the American people generally for us to set aside for a time our concern about the immediate advantages of competitive action, and apply the combined talents and facilities of the whole industry to the solution of some problem that affected the public interest adversely." (GJ Ex. 583); Cf. Remarks of John F. Gordon, President, AMA, and President of GM, July 31, 1963, GJ Ex. 335, p. 2 of remarks).

Minutes of the Engine and Vehicle Modification Task Group Meeting, September 12, 1962, gives the source of AMA policy in this matter as follows:

"The AMA Board of Directors has instructed the Engineering Advisory Committee to solve the vehicle emission problem through industry co-operative effort and to explore any and all avenues necessary to accomplish this." (GJ Ex. 286; Cf. GJ Ex. 258).

On February 7, 1955, the VCP in accordance with a directive of the Board of Directors submitted in draft a plan whereby an information pool would be established and that "research and test data, devices, methods and the like, whether or not the subject matter of a patent or patent application, as may be submitted by any Vehicle Manufacturing Company to the VCP Subcommittee, and owned or controlled by such Company, are to be available on a royalty-free basis to all Vehicle Manufacturing Member Companies and such non-member companies as the VCP Subcommittees may select which agree to conform to the terms of the Resolution of the Board of Directors approving this report." (GJ Ex. 260, p. 1a; Cf. GJ Ex. 285, p. 4).

The plan, however, was never adopted. In place thereof, the Board of Directors of AMA "instruct[ed] legal counsel and the AMA Patents Committee to develop a Cross-licensing Agreement which was the key part of the implementation of the cooperative research and development program." (GJ Ex. 258, AMA Staff Report on Smog Problems to Board of Directors, p. 1). The cross-licensing agreement limited the field of activity to six categories. The Patent Committee Minutes of April 5, 1955 at which this plan for a formal cross-licensing agreement was adopted, contains the following statement (similar ones of which were made many times thereafter by the project and industry leaders): "Mr. Heinen has repeatedly expressed the feeling of his Committee (the VCP) that no one company should be in a position to capitalize upon or obtain competitive advantage over the other companies in the industry as a result of its solution to this problem." (GJ Ex. 292).

This position and its antitrust implications are indicated in a May 10, 1954 AMA document authored by Mr. G. J. Gaudson, former secretary of the VCP, now Detroit Branch Manager of the Society of Automotive Engineers (SAE), as follows:

"Heinen asked whether a company coming across a satisfactory device either submitted by an inventor, developed during the course of normal company research, or during the course of Subcommittee studies should make the device and

its details known to the other companies participating in the Subcommittee work. The alternative, of course, would be for the company to say nothing and then 'scoop' the other manufacturers with an anti-smog device. In view of the common importance of the smog problem to all of the companies and in view of the satisfactory cooperative nature of the work thus far, the individual company approach was not generally favorable. However, it was recognized that very serious legal problems might be involved in the cooperative acceptance and review of device." (GJ Ex. 590).

Mr. J. M. Chandler, then Unit Supervisor of the Engineering Research Department, Engineering Staff, Ford Motor Company (Ford), in an intracompany communication dated November 16, 1954, wrote in part:

"LEGAL ASPECTS OF COOPERATIVE ACTION

"Another subject discussed at this VCP meeting was that of the legal complications involved in a cooperative industry solution to the smog problem. Mr. Cronin, General Manager of the Automobile Manufacturers Association, indicated that the legal study had not yet been completed, and that he was not sure how complex it was going to be. There is some difficulty concerned with antitrust action which is being carefully surveyed. The Subcommittee indicated a general moral feeling of free cooperation, but with no binding agreements legally available, there is still some question as to competition versus cooperation. Whatever the legal solution it would not hurt for us to be competitively prepared." (GJ Ex. 593).

To the same effect, the Minutes of the Patent Committee of April 5, 1955, read in part as follows:

"In discussing the need for a formal agreement as opposed to adoption by the member companies of a Board resolution accepting the report on purpose and procedure, Mr. Willits pointed to the cross-licensing agreement employed between the lamp and automobile manufacturers in solving the headlighting problem."

* * * * * * *

"Mr. Willits raised some fundamental questions as to the extent of accomplishment possible through a cooperative arrangement such as that contemplated here, as opposed to the programs which might be achieved from the strictly competitive approach, it was agreed that, from the standpoint of public relations, concerted action by the members of the industry and their suppliers appeared to be the only satisfactory solution to the problem." (GJ Ex. 260).

The cross-licensing agreement was originally entered into in 1955. It was amended in 1957 and again in 1960. Five years extensions were executed by the signatories in 1960 and 1965. Thus, the basic provisions of the cross-licensing agreement are in effect today. (GJ Ex. 263, 264, 265, and 266). It provides for a royalty-free exchange of patents between the participants and a formula for sharing the costs of acquisition of patents. The provisions of the cross-licensing agreement which accomplish this result are as follows:

"ARTICLE III—LICENSES GRANTED BY EACH PARTY

"(a) Each party to this Agreement grants to each of the other parties and to their respective subsidiaries, a royalty-free, nonexclusive license to make, use and sell and to have others make for it or them Licensed Devices and parts thereof coming under any patents, domestic or foreign (subject to the conditions set forth in paragraphs (b) and (c) of this Article), owned or controlled, either directly or indirectly, by said grantor on July 1, 1955, or at any time thereafter prior to June 30, 1960, or granted at any time hereafter on inventions owned or controlled, either directly or indirectly, by said grantor on July 1, 1955, or at any time thereafter prior to June 30, 1960.

* * * * * * *

"(c) If any of the parties hereto acquires directly or indirectly a patent otherwise coming within the scope of this Agreement at a cost, exclusive of the expense incurred in prosecuting the patent application or negotiating the purchase, in excess of three hundred dollars ($300), no license thereunder shall be acquired by any other party by operation of this Agreement except upon such party sharing the cost of the patent equitably with the first party and with any other parties electing to take a license thereunder." (GJ Ex. 263).

Section (a) provides for a royalty-free exchange of defined patented devices by all participants provided that development costs in excess of $300 are shared equally. As hereinbefore stated, there is admittedly little or no economic incentive for automobile manufacturers to develop and install air pollution control equipment on vehicles they manufacture. (Tr. Vol. XXII, p. 54). Since the results of any industry advances are to be shared by all, there is no private incentive for gain inasmuch as each company must share the benefits of such advantages with the rest of the automobile industry (GJ Ex. 566). Delays in technological development engendered by inadequate manpower or facilities will result in no disadvantage to any company should it become desirable or necessary to install such equipment in the future. At the same time it is apparent that the participants in the cross-licensing agreement possess sufficient resources to engage in competitive research and development programs.

Section (c) provides for a royalty-free exchange, between the participants, of patents acquired from third parties, provided that the purchase price in excess of $300 is shared equally. In effect, this provision presents a third party seeking to market a patent to automobile companies with but a single purchaser—i.e., the whole industry. The provision eliminates price competition among the participants with respect to the purchase of patents from third parties. (Tr. Vol. XXII, p. 53).

The intent to control prices of inventions by the cross-licensing agreement is shown by the fact that this agreement, including the above-quoted provision, was modeled after a similar agreement concerning sealed beam headlights. In discussing this agreement, a report of the VCP dated January 10, 1958 reads in part: "There are some industry precedents established in the arrangements which the industry made to insure multiple sources for Sealed Beam headlight units, and *to set the terms for the maximum royalties to be paid for use of light polarizing material.*" (GJ Ex. 338, underscoring supplies).

The cross-licensing agreement provides a most "favored nation clause" whereby third parties must license all participants at the same royalty rate. (Tr. Vol. XXII, p. 48). The provision of the cross-licensing agreement which accomplishes this result is as follows:

"ARTICLE III—LICENSES GRANTED BY EACH PARTY

"(b) If any party hereto as acquired or does in the future acquire either directly or indirectly the ownership, control, or right to license others under patents otherwise coming within the scope of the Agreement conditioned on the payment of royalty, no license thereunder shall be acquired from such party by and other party by operation of this Agreement except upon the latter's agreeing to pay and paying to the licensor of said first party, royalty at the same rate as such first party would have been required to pay had the licensed article been made or sold by it. Royalties accruing under the provision of this subsection (b), if for sales within the United States and Canada, shall be payable in the next succeeding month of January, April, July or October, as the case may be, following the close of the calendar quarter in which said sales occur. . . . (GJ Ex. 263).

Mr. William L. Scherer, manager of the Patent Department of AMA, interpreted the meaning of this provision for the grand jury. He testified that it enables any other party to the argeement to obtain the same kind of arrangements with respect to rights as the first party making arrangement with a patentee. (Tr. Vol. XXII, p. 46). In other words, if one of the companies acquires a license under a given patent, that company must endeavor to make it possible for any other party to the agreement to also obtain a license under that patent, for which royalty would be paid at the same rate as the first company acquiring rights under the patent would have negotiated. (Tr. Vol. XXII, p. 47). This ensures to anyone else who may want to come into the program, or the that patent, that they will get the same royalty treatment as the first individual does. (Tr. Vol. XXII, pp. 48–49).

This provision of the cross-licensing agreement was intended by the participants to eliminate competition between them in the purchase from third parties of rights under existing patents. This conclusion is based on Mr. Scherer's testimony which was as follows:

"The JUROR. Wasn't the patentee told that it would be available to all of the companies? Or was that kept a deep, dark secret?

"The WITNESS. No, I think that when he came, for instance, if John Doe has a device that he says will solve the problem, and he wanted to come to Company A and deal with that company, he could have done so.

"Now the only understanding is that, if that John Doe, I believe I called him, were to deal with Company B, the only understanding is that he is going to get the same royalty arrangement that Company A has.

* * * * * * *

"The WITNESS. And he will be glad to do that, believe me.

"The JUROR. Well, in other words, he might go into Company A and agree on a royalty of 10¢ an item, let's say.

"The WITNESS. Yes.

"The JUROR. Now, he went to Company B and he is faced with the fact that that is as much as he can get; is 10¢, because the other company has now made it available to them.

"The WITNESS. That's right. But, remember, he has got a lot more volume.

"The JUROR. Well, that may be so or it may not be so. But, it depends on, in other words, his 10¢ now becomes a fixed——

"The WITNESS. Ceiling.

"The JUROR. Ceiling.

"The WITNESS. That's right.

"The JUROR. He cannot go above that ceiling once he submits to one company; he cannot go above that ceiling. He is hooked.

"The WITNESS. Under what we call the "favored nation clause," yes.

"The JUROR. Well, whatever you call it, he is hooked for that amount.

"The WITNESS. That's right.

"The JUROR. Thanks. (Tr. Vol. XXII, pp. 56–57).

The participants to the cross-licensing agreement have agreed upon a method whereby a third party wishing to do business with any participant must agree with his device may be considered by all of the participants through the Automobile Manufacturers Association.

In 1955, the cross-licensing agreement provided in pertinent part:

"Article VIII—Ideas submitted by persons other than parties

"It is agreed that each idea relating to the subject matter of this Agreement submitted by a person other than a party to this Agreement shall be first submitted to one of said parties accompanied by a waiver in a form approved by the Patent Committee of the Automobile Manufacturers Association by which the submitter shall authorize such party to disclose the idea for appraisal and test to any third party or parties and grant immunity to said party as well as to all parties to whom such disclosure is made from all liability to the submitter arising from such disclosure other than such liability arising from the infringement of any valid patent covering the subject matter disclosed. Each such party shall then submit such ideas to the Vehicle Combustion Products Subcommittee for consideration, after which said Party shall report to the submitter the findings of said Subcommittee, and shall file a copy of said report with the secretary of said Subcommittee." (GJ Ex. 263).

This provision was amended in 1957 to read as follows:

"ARTICLE VIII—IDEAS AND INVENTIONS SUBMITTED BY PERSONS OTHER THAN PARTIES

"Nothing in this Agreement shall prevent any of the parties from receiving, considering or purchasing ideas or inventions submitted by others relating to the subject matter of this Agreement. In the event that such ideas or inventions are submitted to a party by a person other than a party to this Agreement or other than a person under contract to assign such ideas or inventions to a party, such party may submit such ideas or inventions to the Vehicle Combustion Products Subcommittee for consideration provided such party has obtained from the submitter a waiver in a form approved by the Patent Committee of the Automobile Manufacturers Association by which the submitter shall authorize such party to disclose the idea or invention for appraisal and test to any third party or parties and grant immunity to said party as well as to all parties to whom such disclosure is made from all liability to the submitter arising from such disclosure other than such liability arising from the infringement of any valid patent covering the subject matter disclosed. The said party shall thereafter report to the submitter

the findings of said Subcommittee, and shall file a copy of said report with the secretary of said Subcommittee." (GJ Ex. 264).

Mr. Scherer testified as follows as to the substantive change worked by the 1957 amendment to Article VIII:

"A. . . . it enables, as I understand it, to have each participating company consider ideas submitted by outside parties, not parties to the agreement, for consideration and test without the necessity of reporting that information to the (other) participant[s] under the cross-licensing agreement." (Tr. Vol. XVII, pp. 44–46).

Plainly, Article VIII of the 1955 Agreement (GJ Ex. 263) requires third parties dealing with any participant to agree to the submission of their device to the Vehicle Combustion Products Subcommittee of the Automobile Manufacturers Association.[5] As amended in the 1957 agreement (GJ Ex. 264), however, it would seem that referral to the VCP was no longer required. (Tr. Vol. XVII, pp. 44–46).

Mr. Van Derveer, however, testified unequivocally that it was communicated to him by both AMA and his superiors at American Motors that the signatories to the cross-licensing agreement had obligated themselves to insure that before any participant dealt with an independent device manufacturer that the device manufacturer must sign an AMA Suggestion Submission Agreement.[6] (Tr. Vol. XXXXVI, pp. 48–51; GJ Ex. 416). Even after the 1957 amendment, AMA continued to recommend to participants that an AMA Suggestion Submission Agreement be obtained from third parties. (Tr. Vol. XVIII, p. 93).

Mr. William K. Steinhagen, a General Motors engineer in charge of their Power Development Group, testified that when a third party came to him with a device, he was instructed to inform the third party of General Motor's obligations under the cross-licensing agreement and to obtain an agreement from the third party allowing tests of the device to be conducted under the terms of the cross-licensing agreement. (Tr. Vol. XXXII, p. 54).

Mr. Harold Lipchick, Vice President and General Manager of the American Products Division, Chromalloy American Corporation, testified that in attempting to market the AMF-Chromalloy device to the automobile company participants in 1964, it was suggested by Mr. Chandler of the Ford Motor Company that the proper method of procedure would be for Lipchick to execute an AMA Suggestion Submission Agreement and to make his initial presentation to the AMA. (Tr. Vol. XVII, p. 50).

It is apparent from the foregoing testimony that the language change in the 1957 amendment worked no substantive change in the requirement that participants not consider third party devices unless an AMA Suggestion Submission Agreement was executed by the third party.

Minutes of the AMA Patent Committee meeting of May 13, 1959, read in part:

"The Committee reconfirmed the position taken at its September 22, 1955 meeting that it disapproved any meeting between industry members and persons who have not signed the Cross-Licensing Agreement unless the outsiders have executed an AMA Suggestion Submission Agreement and that there should be no exceptions to this policy." (GJ Ex. 260).

That AMA highly regarded the method of dealing with third party devices is further illustrated by the following pertinent excerpt from GJ Exhibit 302, an unsigned memorandum dated April 20, 1965:

"Probably not for publication but Mr. Thornton (an AMA employee) says 1957 amendment was made because of antitrust problems in the first agreement. Changed the way people brought ideas to the committees from outsiders.

* * * * * * *

"Also not for publication—Mr. Thornton says the Patent Committee feels we should definitely renew—especially in view of the CID investigation. It would not be wise to discard the agreement at this time."

Mr. Scherer's testimony on this amendment was as follows:

"Q. In other words, prior to the amendment in 1957, anybody who had signed the cross-licensing agreement was obligated, with respect to submit any ideas which they received from outsiders to the Automobile Manufacturers Association Vehicle Combustion Products Committee? Isn't that correct?

"A. That's correct.

"Q. And it was felt in 1957 that there were some antitrust difficulties with that particular method of procedure, was there not?

"A. All I can say to that is that on advice of counsel, it was changed." (Tr. Vol. XVIII, pp. 87–88).

Footnotes at end of article.

Basically, there are three parts of an automobile emitting pollutants. One, the crankcase (blow-by); two, the carburetor and fuel tank (evaporation losses); and three, the exhaust. Before any devices were affixed to cars, the experts estimated that 25% of the pollutants were emitted from the crankcase, 15 to 25% from evaporation losses, and 50 to 60% from the exhaust.

In 1959 it was discovered at General Motors that a positive crankcase ventilation (pcv) valve, used even prior to World War II for the purpose of keeping the crankcase of military and other vehicles free of mud, stand, etc., was effective in the elimination of blow-by emissions from the crankcase. (Tr. Vol. XXIX, p. 72; Tr. Vol. XXXVI, pp. 15–16). As a result, General Motors could have installed the device on its cars and obtained a competitive advantage since this type of device was not covered by the cross-licensing agreement. However, this was not done, but to the contrary, the cross-licensing agreement was amended in 1960 by the addition of five categories covering crankcase and evaporation losses so that the industry could act collectively with regard to these areas. (Tr. Vol. XXXVI, p. 15; GJ Ex. 265).

A July 27, 1959 memorandum from W. F. Sherman of the AMA staff to the EAC states in part:

"Mr. Delaney called attention to the fact that neither of these areas of investigation or development are covered by the present industry Cross-Licensing Agreement. I was, therefore, the unanimous recommendation of the committee and of Mr. Delaney that the Engineering Advisory Committee should immediately request the AMA Patent Committee to amend the Cross-Licensing Agreement to cover these areas, and to do so in the immediate future to permit the work to go forward rapidly." (GJ Ex. 384).

An agreement was then made by the automobile manufacturers to install the pcv valve on all 1961 model cars to be delivered in California only. (Tr. Vol. XXXXIII, pp. 99–100; GJ Ex. 355, 415, 543). This was heralded as a "voluntary" contribution to the elimination of smog by the automobile industry. (Tr. Vol. XXI, pp. 15–17, GJ Ex. 355; Tr. Vol. XXIX, pp. 73–74). However, a document dated November 13, 1959 written by W. S. Berry of American Motors indicates the real motive for the installation of the device on 1961 models. It reads in part as follows:

"There is time to complete our test work on this breather system before the introduction of the 1961 model. The reasons for making the announcement before test work is completed are as follows:

"1. The opportunity for the industry to voluntarily do something in California which will make a major reduction in emissions at a relatively low cost. In advancing this argument the AMA Staff uses a cost to the customer figure of around '$10.'

"2. On December 4th there will be a hearing in Berkeley which will be held between the California State Department of Health to finalize recommendations on tailpipe emissions. An announcement before that date would possibly slow down any regulatory action on this matter. Likewise, this announcement may deter Governor Brown from holding a special session of the Legislature dealing with the air pollution problem." (GJ Ex. 555).

Quite evidently the cross-licensing agreement was not needed for protection or use of any patent. As a matter of fact, no significant patents were then known to exist affecting development of pollution control devices and no lists of patents were then nor have they ever been annexed to the cross-licensing agreement or any extension thereof. (Tr. Vol. XXII, pp. 54–55). It is submitted that the cross-licensing agreement was merely a vehicle to accomplish the non-competitive and delaying activities of the signatories thereto.[7]

The evidence adduced before the Grand Jury clearly developed that the signatories to the cross-licensing agreement had the following understandings and agreements with respect to the installation of motor vehicle air pollution control devices: (A) not to publicize competitively any solution to the motor vehicle air pollution problem; (B) to adopt a uniform date for announcement of the discovery of any air pollution control devices; and (C) to install devices only on an agreed date. (Tr. Vol. XXII, pp. 49–50).

Minutes of the meeting of the Engineering Advisory Committee on January 10, 1958, read in part as follows:

"The Committee report raised a number of questions for decision by EAC. These were taken up in the following order:

Footnotes at end of article.

"(i) ***Statement on exchange of information and publicity on smog research activity.*** The VCP asked concurrence of EAC on this statement which was drafted in August by the VCP members. Mr. Kucher stated that there is no misconception or objection to the objective the VCP has in mind, but he questioned what mechanism would be used; he suggested that specific provision be made for the submittal of plans for speeches and text ahead of time. Mr. Heinen said that the VCP would include such ground rules with the statement.

"Mr. Ackerman commented that there was no doubt about the EAC belief that such a program should be carried out on a cooperative basis. Mr. Chayne moved approval of the proposal, with the instruction that it be sent to the company public relations directors, asking them to join in the effort to carry this out properly.

"The VCP report also called attention to the desirability of re-affirming the idea of a single announcement and a uniform adoption for any device which the industry may decide to use for smog control. Mr. Chayne moved that this view be included with the previous motion; EAC members approved. (GJ Ex. 339; Tr. Vol. XX, p. 78).

The following further excerpts from documents and testimony are illustrations of the understandings and agreements referred to above:

A. As to the agreement not to publicize competitively any solution to the problem:

"1. Grand Jury Exhibit 338, dated January 10, 1958, (Tr. Vol. XX, p. 74), reads in part as follows:

" 'To a large degree, some of the questions in connection with the publication of data involved consideration of publicity effects which often result when some item of interest is released dealing with the smog problem. The Committee believes that it was the intention of AMA in establishing the VCP activity to avoid situations in which competitive publicity advantages would arise and be seized by any one of the company participants. *EAC re-affirmation of this viewpoint would be helpful.*

* * * * * * *

" 'Similarly, there have been some fears expressed that technical developments in the air pollution program, which might happen to occur in one quarter rather than another, could lead to a situation in which some automobile companies might be more favorably positioned for the introduction of an exhaust control device than other companies. Here it has been the VCP understanding from the beginning that the public service aspects of our cooperative work on the exhaust gas problem are such that no company should expect to take advantage competitively by being the first, or claiming to be the first, to offer such a device. *It will be extremely helpful in the further conduct of our program if the EAC will take cognizance of the importance which is attached to this problem end re-affim authoritatively that the companies will participate equally in the public relations benefits that will accrue from a single announcement in the uniform adoption date for any device which may be adopted for use.*' "

The report of the EAC of the same date, January 10, 1958 shows that by vote it reaffirmed "the idea of a single announcement and a uniform adoption date for any device which the industry may decide to use for smog control." (GJ Ex. 339).

"2. Grand Jury Exhibit 345, December 3, 1962 (Tr. Vol. XX, pp. 105–106), reads in part as follows:

" 'The Engineering Advisory Committee is in complete agreement with both the public Relations Committee and the Vehicle Combustion Products Committee with regard to the need for more and better publicity about industry activities in the air pollution field.

" 'The Engineering Advisory Committee does, however, share the concern of the Vehicle Combustion Products Committee regarding the dangers of ill-considered unilateral publicity. The EAC recommends, therefore, that the proposal for increased publicity by the individual companies, as well as by the Automobile Manufacturers Association, be approved with the proviso that such releases concern only "activities" and that releases concerning specific "solutions" be issued by AMA.

" 'It is essential that all releases be coordinated through AMA and that procedures be established to handle such coordination expeditiously.'

"3. Mr. Scherer's testimony on this subject was in part as follows (Tr. Vol. XX, pp. 76–77):

" 'Q. The matter of publicity, is it your understanding that by the terms of the cooperative arrangement in the industry with respect to motor vehicle air pollution control equipment, that no one company would advertise or publicize the merits of its equipment, vis-a-vis other companies in the field?

" 'A. That was my understanding of their intention, yes.'

"4. An interdepartmental letter of American Motors dated November 28, 1962, reads in part as follows:

" 'In the area of press releases there has been a tacit understanding, if not a written policy, that all individual company press releases will be reviewed by the AMA Public Relations Committee and the VCP. Ford has been the only flagrant violator of this policy, since on two occasions they have issued releases that caught the rest of the industry by surprise (announcement of vanadium pentoxide exhaust catalyst in 1957, and blowby control system in 1962).

" 'The current AMA Public Relations Committee recommendation to the Engineering Advisory Committee, which was initiated by G.M. is somewhat difficult to understand. It has been suggested that it is a "veiled threat" to Chrysler because of that company's success (and related publicity) in making their cars meet the California standard for exhaust emissions without an exhaust treating device. The proponents of this approach say that G.M., because of their overwhelming dominance in the field of smog research (see attached sheet for relative air pollution budgets of AMA member companies), are saying to Chrysler, "Slow down on this approach and don't break the industry front or we will completely submerge you, publicity-wise".' (GJ Ex. 542).

"5. Mr. Van Derveer testified as follows concerning a 1957 publicity release by the Ford Motor Company (Tr. Vol. XXXXV pp. 46, [illegible]3):

" 'Q. So, Ford issued a publicity statement on the vanadium pentoxide device, and it achieved nationwide recognition.

" 'A. Yes.

" 'Q. And it was a device? A prototype device had been developed?

" 'A. Yes.

" 'Q. Tested on cars.

" 'A. Yes. Not very extensively, but, yes.

" 'Q. And then there was some unhappiness in the industry over Ford's publicity?

" 'A. Correct.

" 'Q. Now, who was the source of the unhappiness?

" 'A. Well, Heinen was probably the most vocal on the thing.

" 'Q. All right. What did Heinen say?

" 'A. . . . Well, he said lots of things, actually. But, more or less of a breach of a promise; the fact that this put Ford in a lot better light. And just the fact that the company was getting nation-wide attention for something, the other people were working equally hard on other things and they weren't getting any publicity. That sort of thing.

" 'Q. Was there a little feeling that Ford was reaping too much advantage out of its publicity, and, therefore, Ford should not have issued the publicity statement?

" 'A. Well, that was certainly part of it.

*　*　*　*　*　*　*

" 'Q. So, there was an attempt to dampen the publicity that was issued a little while before.

" 'A. It wasn't actually a retraction, I guess.

" 'Q. Not a retraction, but an attempt to dampen down the publicity.

" 'A. As I remember, yes.

" 'Q. What was the impetus of Ford to dampen down the publicity: Was it because Heinen was disturbed about this?

" 'A. I am sure it was Heinen and General Motors being disturbed, too. I am sure General Motors had an opinion on it. I never heard it expressed particularly.' "

B. As to the agreement for the adoption of a uniform date for announcement of the discovery of a device:

"1. In an interoffice memorandum from R. J. Templin, Cadillac Motor Car Division, to J. H. Lamb, also of GM, dated October 6, 1959, Mr. Templin stated:

" 'Please note that we are bound by an agreement through Mr. C. A. Chayne with the Automobile Manufacturers Association to withhold any public knowledge about these devices until a joint industry announcement can be made through AMA. These devices must, therefore, be treated as confidential.' (GJ Ex. 490).

"2. Mr. Scherer's testimony on this point was in part as follows (Tr. Vol. XXII, pp. 49–50):

" 'Q. Have they also had the understanding to adopt a uniform date for the announcement of the discovery of any air pollution control device?

" 'A. I would say that's the way the program has operated, yes.'

"3. Mr. Scherer further testified (Tr. Vol. XX, pp. 75–76):

*   *   *   *   *   *   *

" 'Now, that's a fact, isn't it, that the industry, from that point on [Jan. 10, 1958], has publicized a uniform adoption date for any device that is produced in this field?

" 'A. You are asking me?

" 'Q. Yes, I am asking you.

" 'A. That's correct. There is one thing to be said for that type of thing: Remember that there were some of the participants in the program who may not have been quite ready to go ahead with the adoption of the device as far as their own testing and knowledge is concerned. They were pressed into going ahead with it, much ahead, perhaps, of the time that they were ready.

" 'Yes, and if they weren't ready, they may also have waited until—

" 'A. If they were ready?

" 'Q. The others could wait——

" 'A. That's possible.

" 'Q. —until the device was ready until everybody could put it on at the same time?

" 'A. That's possible. So, it works both ways.

" 'Q. But, there is no doubt about it that the policy has been consistent and that it is right up to this date, that no device has been adopted by any one company on its own; that they all did it at a uniform adoption date; they all put it on at the same time? Is that correct, sir?

" 'A. I believe that's correct.' "

C. As to the agreement to install devices only on an agreed date:

"1. Testimony by Mr. Scherer on this subject was in part as follows (Tr. Vol. XXI, p. 33):

" 'Q. Is this kind of behavior on the part of the individual companies the result of an agreement among all of them to adopt devices at a uniform date, and that one company would not go ahead with the device unless all of the other companies were in the position to go ahead with the device?

" 'A. We did note in the record that there was such an understanding among the companies, yes.'

"2. Minutes of the EAC meeting, dated May 17, 1962, read in part as follows:

" 'UNIFORM ADOPTION AND ANNOUNCEMENT OF SOLUTIONS

" 'At this point Mr. Caplan read the rest of his report and raised for discussion the problems that had arisen as a result of publicity and the supplying of some equipment for engine modification to Los Angeles County officials prior to its being supplied to the State Board. This had resulted in a letter from the County Board of Supervisors, which has been acknowledged but not yet answered, urging AMA action by all of the automobile companies to engage in a similar modification program. Mr. Isbrandt suggested that the handling of these problems required simply that all of the participants be cognizant of the responsibilities already outlined and understood in the EAC and VCP activity.' " (Memorandum Report, EAC Meeting, dated May 17, 1962; GJ Ex. 379).

Thus we have seen that the non-competitive industry program was not limited to research and development but encompassed promotion, installation, and marketing. On this score Mr. Van Derveer testified (Tr. Vol. XXXXVI, pp. 51–55):

"Q. Mr. Van Derveer, this non-competitive industry program concerned not only the research and development but also the installation and marketing of devices, did it not?

"A. Well, what do you mean by devices? You are talking about——

"Q. Devices or systems, any kind of motor vehicle air pollution control equipment whatsoever.

"A. It was all coordinated through the AMA, yes.

"Q. All aspects of any company activity in this area?

"A. Yes."

POSITIVE CRANKCASE DEVICE (BLOW-BY)

A GM document disclosed that the AMA asked all car manufacturers on June 1, 1961, *to give all the reasons that could be developed as to why compliance with* a Congressional request that positive crankcase ventilation (pcv) be made standard equipment on all cars would not be desirable. "It must be recognized that they are specifically looking for problems that will justify a negative decision." commented G. R. Fitzgerald, a GM engineer. (GJ Ex. 504). After the successful installation of the pcv valve in California by all companies on 1961 models, a decision was made not to install the device on all 1962 models nationally. Mr. Van Derveer testified that "the board of directors, of course, are the ones that had to make that decision." (Tr. Vol. XXXXV, pp. 71–76.) A poll or vote was taken at a meeting of the AMA Crankcase Ventilation Task Group of the VCP on January 26, 1961. (GJ Ex. 360 and 442.) Although Studebaker-Packard and American Motors "agreed to the release of positive crankcase ventilation for all 1962 cars," none of the companies did so, in accordance with the industry agreement.[8] (Tr. Vol. XXI, pp. 32–33; Tr. Vol. XXII, pp. 49–50; Tr. Vol. XXIX, pp 107–110, 130–133; GJ Ex. 360 and 442.)

All GM divisions could have supplied the internal crankcase device as standard equipment for 1962, if requested to do so. H. F. Barr, then Chief Engineer of Chevrolet, writing to C. A. Chayne, then Engineer[illegible] V. P. of GM, said in part:

"Would all GM Divisions be in a position to sup[illegible] internal crankcase ventilation as standard equipment for 1962 production?

"(Answer) We could if it was a mandatory GM policy, but we would not willingly do so." (GJ Ex. 474).

Similarly, in a memorandum of the Ford Motor Company dated January 10, 1961, James M. Chandler wrote:

"I have recently checked with John Asselstine of Engine and Foundry regarding engineering release of positive crankcase ventilation devices for nation-wide application. Mr. Asselstine informs me that inasmuch as those devices have been released, nation wide, as a regular production option for 1961 automobiles he sees no reason why they could not be applied on all production in 1962. He also feels that we would be in a position to release the crankcase device nation-wide on all commercial vehicles for 1962." (GJ Ex. 454).

As far as International Harvester was concerned, a September 26, 1961 letter from S. G. Johnson of International Harvester to W. F. Sherman of AMA states in pertinent part:

"H. International Harvester is in position to comply with blowby devices on all motor truck models at any date deemed advisable by AMA. (GJ Ex. 364).

As a matter of fact, the device could have been installed on 1961 models:

"The main reason that the motor vehicle industry did not voluntarily undertake to supply internal venting throughout the country on all its new gasoline-powered vehicles, starting with the 1961 models, was that a need had been established in California which has not been established elsewhere." (Rough Draft of paper presented at ECS–APCA Meeting, by James M. Chandier, Chairman, VCP–AMA, entitled "Current Status and Future Work on Vehicle Emission Control Devices," undated (GJ Ex. 381)).

As a result of this thinking, an interdepartmental letter of American Motors from its VCP member, Ralph H. Isbrandt, dated December 7, 1961, indicates that the AMA Board of Directors as early as December, 1961 determined and agreed that the device should be installed not one year later, in 1962, but two years later, in 1963:

"At the AMA Board of Directors meeting, held December 6, 1961, it was agreed that the Industry would include Positive Crankcase Ventilation devices as standard equipment on all 1963 model cars." (GJ Ex. 556).

An attempt was even made to delay national installation on 1963 models. (Tr. Vol. XXX, pp. 27–32; GJ Ex. 373). Robert J. Templin, Asst. Chief Engineer, Cadillac Motor Car Division, G.M. wrote on September 25, 1961: "To sum it up, there is nothing to prevent our going to positive crankcase ventilation as standard equipment for 1963, if policy dictates it. Our lives will be less troubled, however, if we don't do it." (Tr. Vol. XXXVII, p. 7; GJ Ex. 509). This time, however, the pressure of public officials forced the issue. A memorandum by W. F. Sherman of AMA to the EAC, dated May 25, 1961 reads in part as follows:

Footnotes at end of article.

"The U.S. automobile industry has been asked to help protect the public health by installing 'on your own initiative' a device in all new cars which destroys crankcase fumes.

"Sen. Maurine Neuberger, (D. Org.) made the request in a letter sent Monday to 14 manufacturers of cars and trucks. She suggested that in the event the automobile industry failed to seize the initiative, it would be subject to 'responsible legislation to prohibit the transportation in interstate commerce of vehicles wihout the protective device.'

"Sen. Neuberger noted that the Automobile Manufacturers Association had rejected a request by the Secretary of Health, Education and Welfare that the industry install at the factory a device which destroys crankcase fumes, a factor in air pollution along with auto exhaust fumes." (GJ Ex. 365).

A similar memorandum for use by Mr. Sherman at the EAC meeting of May 25, 1961, also reads in part as follows:

"Since all of the companies are presumably receiving a letter from Sen. Neuberger, I have a specific suggestion to make. First, I would suggest that as in the recent past with similar letters, be referred to AMA for a reply.

* * * * * * *

"Three, I believe it is very much in the interest of the indusrty to take the initiative before it is pushed further on this matter and that the Engineering Advisory Committee should therefore recommend to the Board of Directors at their meeting on June 15 that a public statement be issued saying that inasmuch as service experience has proved to be at least reasonably satisfactory, it is being recommended to all member companies that as their tooling and manufacturing permits, they proceed to apply the device to all vehicles for sale in all parts of the United States.

"If this action is not taken by the industry, it seems certain that there will be Federal legislation.

"It also seems to me that the opportunity provided in this instance to make a very big distinction between these inexpensive devices and exhaust control devices for use in California, which are more expensive and which are applicable primarily to the photo-chemical smog problem, might be utilized to position the industry for the future, although we certainly can't ignore the possibility that similar pressures will arise with regard to any muffler devices that are adopted at a later date in California." (GJ Ex. 366).

As a result of this pressure, the attempt to delay installation of the device until at least 1964 failed, and the companies agreed and did install the pcv valve on all 1963 models nationally. (Tr. Vol. XXXXV, pp. 24–25). The same valve that was installed on all 1961 models in California was used nationally on 1963 models, indicating that bar the industry agreement, the device could certainly have been installed nationally at least on 1962 models. (Tr. Vol. XXXXII, pp. 101–102).

CLOSED CRANKCASE DEVICE

After the installation of the pcv valve, it was discovered that the slight remaining emission of pollutants from the crankcase could be eliminated by piping it into the air cleaner where it would be completely dissipated. As a result the Motor Vehicle Pollution Control Board (MVPCB) of California adopted an amended test procedure on December 18, 1962 which could only be met by the installation of the closed type system. New York State officials, too, wanted a closed system. The EAC reviewed both the California and New York situations and reached the conclusion on March 1, 1963 "that the industry definitely does not want to be forced into putting the new systems [closed blow-by on New York cars for 1963 and 1964." (Tr. Vol. XXXVI, p. 151). Since it seemed doubtful that New York would accept less than California for a crankcase device performance, the EAC decided that California was the place to take a firm stand against the new higher capacity systems. To enforce their position, the EAC asked each member company to provide technical information to show why it was impractical to install high-capacity devices for the years 1963 and 1964, (GJ Ex. 507). The Committee was delegated by Mr. Chayne, GM's vice president in charge of engineering, to prepare a specific list of technical problems which might prevent General Motors Car Divisions from supplying crankcase ventilation systems on the 1964 models which would meet the new high flow requirements and still be reliable in all respects. (Tr. Vol. XXXVI, pp. 149152; GJ Ex. 507). (Cf. GJ Ex. 457, a Ford document, which reads in part: "In March we told California we . . . questioned

our . . . readiness for closed systems. Early application for certification [by Chrysler] would cast doubt."

In an interoffice memo, H. P. Barr, GM's member on the EAC, on March 28, 1963, wrote in part:

"I have recently had a call from Mr. Paul Ackerman of Chrysler which indicates they are pulling back their 1964 start of production releases and will release later, effective January 1, 1964, if required at that time by the California law. We are, of course, all hopeful that this will be further extended to start of production of 1965 models before time for this action arrives.

"It is therefore quite important that no General Motors Division make any changes in their 1963 releases for start of 1964 model year production. Since changes would jeopardize the industry position that is being taken with the Air Pollution Board of California." (GJ Ex. 478).

In an intra company memo, Robert Sorenson of Chrysler informed P. C. Ackerman, its EAC member, on January 11, 1963, in part as follows:

"Attached is a letter received from Ben Jensen, Executive Officer, California Motor Vehicle Pollution Control Board officially advising us of the action of December 18, 1962 meeting of the board. His letter indicates that two closed crankcase system devices were approved for both factory and used vehicles . . .

* * * * * * *

"AMA staff was not favorable to an immediate approach and Harry Williams has taken the matter over personally. I understand that he will discuss it with some of the California Motor Vehicle Pollution Control Board members at a pre-established meeting early in February.

"Because of Chrysler's commitment to handle this on an industry basis, there appears to be nothing further we can do on this matter at this time on a Chrysler only basis." (GJ Ex. 446).

In an interdepartment letter from Van Derveer to Isbrandt, also American Motors EAC member, dated April 29, 1963, American Motors' position is stated as follows:

"It is the writer's and C. Harbea's opinion that for our 1964 production we have no other choice but to comply with New York's criteria by either the procedure just outlined or by installing the 'closed' system hardware that is released for California production commencing January 2, 1964. However, if we release the '64 California'fiz' for car one 1964 New York State production, we will run afoul of the A.M.A. policy on this matter, and as you are aware various industry representatives feel quite strongly that industry solidarity is a must on this matter." (GJ Ex. 558).

However, the industry's attempt to delay the installation of the closed blow-by device to the start of production of 1965 models failed since the MVPCB forced the installation of the closed blow-by system as of January 1, 1964. (Tr. Vol. XXI, pp. 68–73; Tr. Vol. XXXVI, pp. 155–157, GJ Ex 503). AMA's position at the meeting of the MVPCB, in regard to this matter, is indicated in the following GM interoffice memo dated January 24, 1963, as follows:

"At the December meeting, the Board decided to require 'closed' type crankcase devices on new cars beginning with the 1964 model year. George Delaney, representing the AMA strongly objected to the Board's action. According to reports, Delaney claimed that the manufacturers had already firmed their 1964 designs and changes could not be made to meet the deadline.

"According to rumors, the AMA was so incensed at the Board's action, they resolved to boycott future meetings, and since the AMA was not represented at the January 17 meeting, a proposal was adopted which may be costly to the industry. Of course, the action might have been taken whether or not the AMA was represented, but the Board didn't even have the benefit of hearing the industry's objections." (GJ Ex. 376).

As to the ability of the auto companies to install a closed blow-by system on their cars, our expert, Wallace Linville, testified:

"Q. Is there any reason why that couldn't have been done by the industry prior to 1964?

"A. No. It is similar to a system that you find and have found for years on particularly dump trucks where they are operatiing in very dirty areas, and again on the army equipment that we mentioned in the second World War, where they are running in convoy, the vehicles following the first vehicle are operating in very dusty terain, and as a result of this they have had the system closed by means of this tube to the air cleaner for a good number of years, so I see

no reason why this should have offered a substantial or major problem at all." (Tr. Vol. XXXXI, p. 25).

Errol J. Gay a consultant for TRW and others, and an apologist for the auto industry, when asked the same question testified:

"A. Hell, they could have done it prior to 1938, if necessary." (Tr. Vol. LVII, p. 73).

EXHAUST DEVICES

By California statute passed in December, 1959, all automobile manufacturers were required within one year following certification of any two motor vehicle air pollution control devices to affix an air pollution control device on all cars sold.

Chrysler Corporation developed its Cleaner Air Package (CAP), perhaps as early as 1960, (Tr. Vol. XXIX, pp. 18–19, 30). In a memo dated October 5, 1961, D. F. Diggs of E. I. Du Pont, reported:

"I asked Heinen why Chrysler did not seek California certification of their vehicles without devices if they are as good as he says they can be made. While admitting that favorable publicity would result, he was very forceful in telling me that if this was done Chrysler would be severely chastised by the rest of the industry. He reminded me that the AMA agreement says no one company will gain any competitive advantage because of smog, and that Chrysler was a relatively small cog in the industry. He indicated Ford and GM were calling the shots and implied that Chayne was the industry mastermind." (GJ Ex. 183).

The CAP system consisted of a valve (part of which was patented) and adjustments of the carburetor, distributor and spark timing. Several technical papers on the subject were written by Chrysler employees, Heinen and Fagley, and published by SAE. (Tr. Vol. XXX, pp. 105, 120–23.) Despite an understanding among AMA members to deal only with the California Motor Vehicle Pollution Control Board and not with the Los Angeles Pollution Control District and its then executive officer, S. Smith Griswold, Mr. Heinen dealt with Mr. Griswold, applied for state certification of the CAP, installed the device on 100 cars as a test, and agreed to fulfill specifications contained in Los Angeles County car purchasing invitations for devices which would control exhaust pollution to the extent of emitting no more than 300 ppm of hydrocarbons and 1.5% of carbon monoxide. (Tr. Vol. XXIX, p. 119.)

In early 1964, Chrysler began to deliver cars to the County of Los Angeles with the CAP system affixed. All told about 1,000 cars were delivered in 1964 with that system. (Tr. Vol. XXIX, p. 120.) The fact that Chrysler got the order to supply cars for Los Angeles County in 1964 was resented by the rest of the industry as a breach of the industry agreement and great effort was made to bring Chrysler back into the fold, which was successful as will be hereinafter shown. (Tr. Vol. XXX, pp. 130, 140–41; GJ Ex. 183, 226.) The result of Chrysler's action in supplying 1964 cars to the county resulted in Ford, too, offering cars equipped with an exhaust device to the county in 1965 which controlled emissions to the required degree.[9]

By the end of 1963 and early in 1964, it was quite apparent that the California Motor Vehicle Pollution Control Board (which required that emissions be limited to 275 ppm of hydrocarbons and 1½% CO) would certify at least two devices being produced by independent (not automobile) manufacturers thereby triggering the law and compelling the installation of air pollution exhaust control devices on all 1966 models offered for sale in California in late 1965. (Tr. Vol. XXXVII, pp. 33–37; GJ Ex. 402).

Every effort was thereupon made by the industry members of AMA to delay the installation of such devices at least until 1967. (GJ Ex. 339, 405). A memorandum dated March 9, 1964, from William Sherman of the AMA staff (Secretary-EAC Committee) to his superior Mr. Harry Williams, Managing Director of the AMA, reads in part:

"While we certainly have the objective of holding the line until 1967 models, we know that the stated purpose of the California MVPCB is to approve two catalytic devices in the next few months and trigger the law so it will apply to 1966 models.

"It semes to me that we would be exercising very poor judgment if we suggested or implied that we wanted them to hold off the triggering of the law, or to let ourselves get into any controversial pisition about it.

"*If they do* act in the near future to approve the catalytic devices, our companies would probably have to take the position, *anyhow*, that there is not

Footnotes at end of article.

enough engineering time to fit the catalytic converters under the frames and chassis of cars in time to meet the schedule of 1966 model production and there would be a strong likelihood of various delays until 1967 introductions.

"It would be very much to our advantage to avoid this topic—shrug it off or ignore it—for a month or two. In the interim a lot of things might change in the picture, including even the withdrawal of the catalytic devices now on tests when the submitters analyze the future possibilities for themselves.

"Thus the problem will have some tendency 'to go away' if we don't aggravate discussion of it at this time." (GJ Ex. 402; Tr. Vol. XXII, pp. 14–15).

On March 10, 1964, prior to any certification of third party devices by the MVPCB but in anticipation that such certification was imminent, the AMA issued a carefully worded press release announcing "that member companies have set a target date of the fall of 1966 in their programs to make 1967 model automobiles and passenger car-like trucks for sale in California comply with the state's motor vehicle emissions standards." (GJ Ex. 407).

The EAC at a meeting on January 17, 1964, had adopted the following resolution:

"Members of the Engineering Advisory Committee resolve that as engineering representatives of the member companies of AMA they adopt the goal that starting with 1967 models, all American-built passenger cars and passenger car-like trucks to be sold in California meet the California Exhaust Standard of 275 ppm hydrocarbon and 1½ per cent CO; further, the Engineering Advisory Committee will report to the AMA Board of Directors their intention to proceed with product engineering programs on each of the various engine and transmission combinations and, by January, 1965, further report to the Board of Directors whether necessary changes can be made in time to meet the target date, the beginning of 1967 model production." (GJ Ex. 399; Tr. Vol. XXX, pp. 72–73).

Pursuant to this EAC resolution, the AMA Board of Directors at a meeting on February 26, 1964, accepted the EAC recommendation, and on motion recommended to all companies that they make it the basis for their individual action. (Tr. Vol. XXX, pp. 71–72; GJ Ex. 405). Subsequently, the March 10 press release was issued. At a joint meeting of the AMA Public Relations Committee and the EAC on March 3, 1964, the reasons for the selection of the March 10 date for the press release were given:

"[Mr. Misch, the representative of the Ford Motor Company to the EAC and also its (EAC's) chairman] advised . . . that the Board had discussed the timing of a press release and desired that such a press release should be made on March 10, before the State Motor Vehicle Pollution Control Board meets on the 11th, but that the industry plan should be reported to the Governor and officials of the Motor Vehicle Pollution Control Board before release is made." (GJ Ex. 401).

The lack of sincerity of the EAC resolution is shown by the fact that the references to product engineering indicated that such engineering had not yet begun. Actually, the Chrysler CAP had already been factory produced on 1964 cars for Los Angeles County. The GM ManAirOx system, the Ford Thermactor system, and the American Motors Air-Guard system, whereby in each the exhaust is burned in the exhaust manifold with the addition of air from an air pump, were then sufficiently ready for production (except for the pump) so that when compelled to do so later in 1964, both GM and Ford announced their ability to apply the device on 1966 models. (GJ Ex. 410). As for the pump, a crash program commenced at GM early in 1964 produced the Saginaw pump within five or six months (Tr. Vol. XXXVII, pp. 32, 42).

As a matter of fact Ford was preparing for Job 1, 1966 with its Thermactor system while adhering to the AMA attempt to delay installation of any exhaust device at least another year. A Ford confidential internal memorandum dated June 26, 1964 reads in part:

"It became apparent that the Board was positioning itself to approve two or more exhaust treating devices in mid 1964 so that 1966 models would need to be equipped with exhaust, treating devices.

"In light of these actions, the automobile industry through the AMA reviewed its position relative to the California situation. On March 10, 1964, the A.M.A. board of Directors announced that it had adopted a goal of Job 1, 1967 for supplying passenger cars and passenger car-like trucks to California which would

meet California's exhaust requirements. At the same time, the Executive Office directed that the Company be prepared to meet the California exhaust requirements by Job 1, 1966.

* * * * * * *

"It should be recognized that our external program as presented to California is to meet Job 1, 1967, but that our internal program is to meet Job 1. 1966. It is recommended that the 1967 goal remain our public posture." (GJ Ex. 599).

Apparently GM and Ford would have continued their opposition to the installation on 1966 Models of an exhaust device or system, but the possibility of Chrysler's application being granted for certification of its Cleaner Air Package thwarted their hopes:

"There is one disturbing element as far as GM and Ford are concerned in the position they have taken. This is the fact that Chrysler *may* receive certification in California for their Clean Air Package; if so it is doubtful if Ford and GM can delay until 1967 the installation of comparable systems." (Memorandum Report by D. R. Diggs, E. I. Du Pont, dated July 8, 1964, GJ Ex. 190).

FURTHER DELAYING TACTICS

The collective activities of the automobile manufacturers to delay the marketing and application of air pollution exhaust control devices and not take competitive advantage of each other is illustrated by the following instances:

(1) *Since the industry was fortified from the beginning of the program with* the agreement among its members not to take competitive advantage over each other, all auto manufacturers were able through the years to stall, delay, impede and retard research, development, production and installation of motor vehicle air pollution control equipment.

As early as January 20, 1959 the Scientific Director of General Motors, Mr. J. M. Campbell, complained to Dr. J. M. Hafsted, the head of GM's scientific laboratory that "Our effort thus far has been at a minimal level required to cover essential areas of this problem while at the same time protecting other essential research programs at current levels." (Tr. Vol. XXXXV, p. 23; GJ Ex. 492).

On September 10, 1962 Dr. Hafsted expressed his concern in similar vein in writing to Mr. L. C. Gead, an executive vice president of GM, as follows: "It is my conviction that this problem needs more attention than it has been getting all along the line in our engine development programs." (Tr. Vol. XXXXV, p. 26; GJ Ex. 493).

A letter dated January 27, 1964 written by Mr. Howard Dietrich, of the Rochester Products Division of GM, to one K. F. Lingg, states that "Mr. Gordon [then the President of GM] feels, and has publicly stated, that anti-air pollution vehicle developments are 'agonizingly slow.'" (Tr. Vol XXXXV, pp. 34–35; GJ Ex. 494).

Dr. Donald Diggs, Asst. Technical Manager of the Petroleum chemical division, Du Pont Corporation, one of the witnesses before the Grand Jury, wrote several reports evaluating the attitude of the automobile industry towards the development of curative smog devices, such as that of April 21, 1959 which contains the following statement:

"They [referring to the big three automobile manufacturers] are not . . . interested in making or selling devices . . . but are working solely to protect themselves against poor public relations and the time when exhaust control devices may be required by law." (GJ Ex. 182; Tr. Vol. XLV, p. 29–30).

Dr. Diggs also wrote a report dated May 31, 1962 in which he gave the following cogent description of the industry's attitude:

"Therefore, they cannot justify an extensive research program because the competition might devise a solution which, while perhaps not as effective, would be less costly to the motorist. The only incentive is to just barely solve the problem at the minimum cost. For that reason, each company is reluctant to spend large amounts of their own money for the development of cures." (GJ Ex. 186).

Dr. Diggs testified that he felt the industry could have pushed more rapidly than it did toward a solution of the smog abatement problem, inasmuch as their work was conducted "at rather low levels of activity." (GJ Ex. 198; Tr. Vol. XIV, pp. 155–156).

An official of the Maremont Automotive Products Company volunteered a statement to officials of the Du Pont Corporation which is contained in a report dated May 19, 1960 which confirmed Du Pont's thinking in regard to the automobile manufacturers that they "were keeping up a good front, but were not push-

ing as rapidly as they could toward a solution of the smog abatement problem." (GJ Ex. 196).

As a matter of fact, one of the functions of the AMA smog working group, according to Mr. James Chandler of the Ford Motor Company, was to "contain" the smog problem. Mr. Chandler was of the view as of May 21, 1959 that the problem "is not bad enough to warrant the enormous cost and administrative problems of installing three-million afterburners." (GJ Ex. 418).

J. D. Ullman, another technical expert in the petroleum chemical division of the Du Pont Corporation also wrote reports on the dilatory approach of the automobile companies toward smog control measures which contain the following statements:

"The automotive industry as a whole has taken a very firm position in relation to the California authorities. Basically, the automotive manufacturers would seek to avoid installing a reactor of any sort on a car because it adds cost, but provides no customer benefits such as improved engine performance or styling advances. [As a result] A smog abatement device will be installed on cars for California market only after being approved and requested by the Government of California." (GJ Ex. 194 dated January 19, 1960).

"We gathered that the automobile industry will continue to do whatever it can within the scope of California legislation and of political pressure to postpone installation of exhaust control devices. The crank case vent will be pointed to as a constructive step by the automobile industry and will be given as much credit as possible for reducing hydrocarbon emissions from the automobile." (GJ Ex. 195, dated April 22, 1960).

(2) The air injection system developed by General Motors was fully described in a paper read before the Society of American Engineers on March 12–16, 1962, entitled, "A Progress Report on ManAirOx-Manifold Air Oxidation of Exhaust Gas" (GJ Ex. 282), but it was not installed on GM cars until all of the automobile companies simultaneously announced antismog systems for all 1966 California models.

(3) As early as 1958 Charles Heinen, the engineer in charge of the air pollution control program at Chrysler, and his assistant, Walter S. Fagley, Jr. co-authored a paper entitled, "Maintenance and the Automobile Exhaust." (Tr. Vol. XXX, p. 105). A second report followed in May, 1962. (Tr. Vol. XXX, p. 120). This paper was omitted from an SAE book entitled, "Vehicle Emissions" published in 1964 which purported to contain an anthology of all SAE papers of significant contribution to the air pollution problem. (Tr. Vol. XXX, p. 123; Tr. Vol. XXX, p. 91). Evidently the omission was influenced by Heinen's desire to equip all cars sold in California in 1962 with the CAP. (Tr. Vol. XXX, pp.132–136, CJ Ex. 448).

Moreover, when Chrysler decided to submit their Cleaner Air Package to the California MVPCB in October, 1963 for certification "the rest of the industry felt that this was a breach on the part of Chrysler of the Automobile Manufacturers Agreement [which] specified that all manufacturers would work together as an industry rather than as individual companies. . . . The final straw . . . came when after Chrysler had submitted their Clean Air Package to the Board . . . the County government decided that wherever possible they would buy only Chrysler vehicles. This, they stated, was to show their appreciation of the attempts by Chrysler to develop a smog-free automobile." (Tr. Vol. XXX, pp. 110–141; GJ Ex. 226).

Despite the success of the CAP, in 1964 Chrysler showed that it came back into line by joining in the aforementioned resolution calling for product engineering and delay of installation until the 1967 models, and by not equipping its cars with the CAP system until installed by all manufacturers on 1966 models to be sold in California. (Tr. Vol. XXIX, pp. 121–122). Chrysler's concern that the industry cooperative smog program be kept intact is clearly evident from a report by R. A. Pittman of the Ford Motor Company concerning a meeting with Bob Sorenson of Chrysler, dated February 6, 1964:

"NOTES ON MY DISCUSSION WITH BOB SORENSON CONCERNING 'SMOG'

"B. Chrysler management is sorry that things have progressed to the extent they have in Los Angeles County and they have been trying to determine how they can back off of what's been said already to Los Angeles County.

*   *   *   *   *   *   *

"D. Bob again emphasized that his company wanted nothing but a cooperative effort and would entertain any other suggestions as to how to get back on a cooperative basis." (GJ Ex. 461).

A handwritten note on this document written by Arjay Miller, President of Ford, dated February 18, 1964 reads as follows:

"I think Chrysler is playing us as suckers. They get all of the favorable publicity and the *car sales*, while giving up nothing." (GJ Ex. 461).

Despite the pressure of the industry, on March 13, 1964 the MVPCB notified each automobile manufacturer that the Board was then testing four exhaust control devices on an accelerated basis, two of which if certified would automatically trigger the mandatory aspects of the law requiring 1966 models to meet the standards. In a letter to Mr. John F. Gordon, then President of AMA, Dr. J. B. Askew, Chairman of the MVPCB, stated that he was hopeful the industry would "reevaluate your policy decision and work with us to achieve exhaust controls for 1966 models." (Tr. Vol. XXX, p. 98, 99, GJ Ex. 447).

On June 17, 1964 formal approval was given by the MVPCB of California to four devices manufactured by independent concerns outside of the automobile industry. Thereafter, on July 7, 1964, in response to a MVPCB request that the individual car manufacturers present their plans with respect to meeting the California standards for 1966 models required by the certification of outside devices, the automobile companies declared their intention to apply air injection systems (General Motors, Ford and American Motors) and an engine modification system (Chrysler) for 1966 cars sold in the State of California (GJ Ex. 419). This determination was formally announced by the industry at a presentation made to the MVPCB on August 12, 1964. The pressure of events therefore, compelled the car manufacturers to advance the application date of exhaust devices at least a full year in advance of their resolved plans and then only to meet the requirements of law.

The Chrysler Corporation could actually have installed the CAP on their 1966 model automobiles, according to a report of Mr. J. E. Yingst of the TRW Corporation dated June 24, 1964, which reads in pertinent part as follows:

"During the last month I have met at the four major automobile corporations with the staff and research level engineering people who are responsible for the exhaust emissions control programs in their respective corporations. These meetings were in conjunction with the presentations of the Texaco–TRW work on a catalytic control system and in response to the interest on the part of Ford, American Motors, and General Motors in our air pump.

* * * * * * *

"(4) Chrysler stated without reservation that they have now engineered their combustion control system into all of their car models and could, if required, offer the system on even their 1965 cars." (GJ Ex. 420).

EVAPORATION LOSSES

As early as June 1958, J. T. Wentworth, a member of the GM research staff prepared a technical paper on the subject of "Carburetor Evaporation Losses" which was published in a compilation of technical papers presented under the auspices of the SAE. This paper was first discussed at a meeting of the Induction System Task Group held on January 14, 1958. (Tr. Vol. XXI, pp. 96–97; GJ Ex. 280). Wentworth's tests were analyzed in his paper and the results showed that evaporation losses of unburned hydrocarbons were as great as those normally emitted from the tailpipe. (Tr. Vol. XXI, p. 98).

On September 16, 1961 a GM engineer named H. H. Dietrich obtained a patent on a method to control evaporation losses which was assigned to General Motors. His application for this patent was filed on August 8, 1960. General Motors thus knew of the Dietrich system and the art involved in its invention as early as 1960 (Tr. Vol. V. p. 35; GJ Ex. 82).

It should be noted that twenty different papers were written on this subject from 1958 to 1964. (Tr. Vol. XXI, p. 123). A report entitled "Fuel System Evaporation Losses" was issued by the AMA in September, 1961. (Tr. Vol. XXI, p. 113). Clearance for release of this report to the California authorities by the member companies of AMA was not given until March 3, 1965, because, as Mr. Linville testified:

"It would seem fairly reasonable that this report would have triggered a great deal of comment and a great deal of criticism of the industry when there were

certain cars over 2000 percent higher than other cars, so it seemed that this could easily have been the reason that this report was kept internal and not allowed to be read by outsiders until modifications could have been made to bring these high emitters down more nearly in line with the low emitters." (Vol. XXI, p. 114–119; GJ Ex. 391 (d); Tr. Vol. XXXXI, p. 37; Cf. Memo. report of VCP Committee meeting held on Sept. 16, 1960, GJ Ex. 351, p. 1).

The cross-licensing agreement was amended in 1960 to include fuel system evaporation losses, and Ford and Studebaker began a study of this problem in that year. (Tr. Vol. XXI, pp. 100–101, 106). Dr. Norman Alpert, Assistant Director of Research at the Esso Corporation testified that if something had then been done to control evaporation losses it would have been equally as important as the elimination of blow-by emissions. (Tr. Vol. V. p. 13). Most members of the Induction System Task Group were of the opinion that carburetor evaporation running losses could be eliminated in March, 1961. (Tr. Vol. XXI, p. 111, Tr. Vol XXX, p. 155; GJ Ex. 389). Yet the minutes of the Fuel System Emission Task Group of the VCP disclose that as of October 15, 1968 "relatively little is being done by the individual companies on vapor loss control." (Tr. Vol. XXI, p. 12; GJ Ex. 390).

In June, 1959, Union Oil Co. developed a system to eliminate evaporation losses but although tested by the industry through AMA it was ignored (Tr. Vol. IV, pp. 19–26, 43–45; GJ Ex. 52, and 54). Even to date the auto manufacturers maintain that there is no practical, economic or feasible system to control evaporation losses, although a Ford, a Chrysler, and a GM car were equipped with a charcoal filter developed by the Esso Corporation to control such losses, Esso having furnished each of these companies with a car of its own manufacture equipped with the device on April 4, 1966. (Tr. Vol. XXI, pp. 125–127; GJ Ex. 393, 395). Dr. John Gerrard, project engineer for the Esso Research and Engineering Company, Linden, New Jersey testified that the Esso Corporation system (which controls better than 95 percent of such losses), was successfully tested on these cars. (Tr. Vol. V, p. 19; Tr. Vol. VI, p. 5). The response of the automobile industry to the Esso system, known as the ELCD system, ranged from hostile to "spotty," although all except Ford are still testing the systems and they agree, in general, with the results obtained by Esso (Tr. Vol. VI, pp. 28–33; Tr. Vol. V, pp. 31–32). This system involves no major engineering change in the motor despite assertions to the contrary by industry spokesmen. All that is required are minor carburetor modifications and a tube which runs from the gas tank vent to a canister filled with charcoal which acts as a filter for the polluting omissions. (Tr. Vol. VI, pp. 51–55).

The estimated cost of the system as original equipment would run from $5 to $7, but in great volume it would come down from this figure. (Tr. Vol. V, p. 27).

On September 23, 1964, more than six years after publication of the Wentworth paper and three years after issuance of the Dietrich patent, GM concluded that: "It is necessary . . . for us to begin development programs on devices to control these [evaporation loss] emissions." This action was taken only after the California Air Pollution authorities had advised they would take steps in October, 1964 to require evaporation loss limits on fuel tanks and carburetors. (Tr. Vol. XXXVII, p. 95; GJ Ex. 9524).

OXIDES OF NITROGEN

Oxides of nitrogen (NOx) is a recognized pollutant emitted from the automobile exhaust together with hydrocarbons and carbon monoxide. This noxious contributor to the smog problem can be reduced by recycling the exhaust gas back into the combustion chamber. The general technology for its reduction has been known for many years, since the exhaust gas recycling system for reducing emissions of oxides of nitrogen was developed and patented in 1955. (Tr. Vol. V, pp. 8–10; Tr. Vol. XIX, p. 128). In 1962 a paper written by Dr. R. D. Kopa of UCLA in conjunction with Messrs. Jewell and Spangler described a 69–80% reduction accomplishment in nitrogen oxide emissions. (Tr. Vol. XIX, pp. 125–126).

Mr. Albert Jesser, a research and mechanical engineer employed by George Cornelius at his laboratory in San Pedro, California described a device for the reduction of oxides of nitrogen developed at the Cornelius laboratory which tested well below the 350 parts per million standard established by the State of California, and reduced NOx emissions 85%. The cost of this device to the consumer is negligible. (Tr. Vol. XIX, pp. 129–132; Tr. Vol. XIX, p. 128).

Mr. Cornelius is a well-known inventor, formerly associated with the Holley Carburetor Company, who has done extensive work on research and development of motor vehicle air pollution control systems and devices. (Tr. Vol. IV, pp. 51–52).

The automobile industry was notified of the existence of the Cornelius device in the latter part of 1960 (Tr. Vol. XIX, p. 184), yet none of the companies took any particular interest in the device, and the impression Jesser had of the Ford attitude toward his device was that "this is a sort nuisance." (Tr. Vol. XIX, p. 148). There were no tangible offers or responses from any automobile manufacturer. (Tr. Vol. XIX, p. 141).

Robert Van Derveer of American Motors testified on June 29, 1967 that none of the automobile manufacturers have come up with a device or system to control the emissions of oxides of nitrogen. (Tr. Vol. XLVI, p. 34).

DIESEL ENGINES

Contrary to popular belief, diesel engines do not emit hydrocarbons or carbon monoxide as do gasoline engines; they do, however, emit irritating smoke and odor. Here again, only lip service was given to correcting the problem.

In a statement made before the Muskie Committee (GJ Ex. 429, at p. 931), Dr. P. H. Schweitzer of Schweitzer & Hussmann, State College, Pa., a recognized authority on diesels, said to park:

"I shall not absolve the diesel engine of its polluting effect. I have raised my voice repeatedly in the past against diesel exhaust smoke and odor. In September 1954, at the fifth international symposium on combustion, in Pittsburgh, Pa. I said:

"Even enlightened self-interest should introduce the industry to take this matter [noise, smoke, and odor] seriously, more seriously than it has in the past. It is easy to predict that government—State or municipal—will soon act if we do nothing about it. An incensed public may force legislators to enact unwise laws to the detriment of all of us."

"The Automobile Manufacturers Association, which received a copy of my talk, took my advice to heart and formed a task force, on diesel emmissions When? Ten years later, in March 1964."

Our expert, Wallace Linville, testified as follows on this problem:

"Q. Can you tell us of any other methods which could have been used since 1955 to reduce smoke and odors?

"A. There are several. Lubribol has to do largely with control of smoke. It is a fuel additive and very adequate for the control of smoke. It has very little effect on odor. The fumigation I described a few days ago is a means of getting better combustion in the combustion chamber of the diesel engine and this is utilized in controlling both smoke and odor, and the first paper that was written on this by Mr. Schweitzer was in 1957 entitled "Fumigation Kills Smoke." Mr. Schweitzer was with the Penn State University at that time." (Tr. XXXXVII, p. 7).

No manufacturers of diesel engines have utilized Lubrizol or other types of afterburners satisfactory in both smoke and other control, except from the economic standpoint. (Tr. XXXXVII, pp. 8–11).

OTHER APPROACHES

Reliance on the agreement not to compete in the research, development, manufacture and installation of air pollution control equipment apparently enabled the automobile manufacturers to disregard several other approaches to the problem, thus further delaying its solution.

For instance, the late 1950's Ralph Heintz, inventor, developed and patented a stratified charge engine (Tr. Vol. VIII, pp. 10, 12, 25–27) which reduced hydrocarbon, carbon monoxide, and oxides of nitrogen emissions, while at the same time effecting a savings in gasoline consumption (Tr. Vol. VIII, pp. 22–25). Moreover, the stratified charge engine would replace the conventional engine with little or no additional cost to the consumer (Tr. Vol. VIII, pp. 27–29). The development of this engine was publicized generally so that the automobile manufacturers knew of its existence and what it would do (Tr. Vol. VIII, pp. 13–18, 30–31). In fact, Victor G. Raviole, former executive director of the Ford engineering staff, stated on several occasions in the early 1960's that the major automobile companies were investigating such an engine and on one occasion predicted that it might be ready for production before 1965 (Tr. Vol. VIII, pp. 29–30, 33; GJ Ex. 607). However, the automobile manufacturers have evidenced little faith in

this approach and no such engine has been produced by any of them (Tr. Vol. VIII, pp. 16, 33–35, 38–39; Tr. Vol. XXXI, pp. 166–168; Tr. Vol. XXXII, pp. 158–160; Tr. Vol. XXXV, pp. 158–159).

Similarly, George Corneilius has developed and patented a direct flame afterburner and an exhaust recycling unit which have proven effective in reducing hydrocarbons, carbon monoxide, and oxides of nitrogen (Tr. Vol. IV, pp. 61–64, 77–79; Tr. Vol. XIX, pp. 130–131). A test by Scott Laboratories shows that with this afterburner hydrocarbons were reduced to 28 ppm and carbon monoxide to 0.95% from 620 ppm hydrocarbons and 4.65% carbon monoxide (GJ Ex. 62) Mr. Cornelius estimated that, if produced in large volume, the combined package (afterburner and recycling devices) would cost the motor vehicle manufacturers about $25 to put on new cars (Tr. Vol. IV, p. 92). However, the major automobile companies have exhibited little or no interest in these devices for controlling automotive pollution (Tr. Vol. IV, p, 57; Tr. Vol. XIX, pp. 132, 134, 141–142, 151). In fact, at a meeting in December, 1963, William Gay, Executive Engineer, Engine and Foundry Division, Ford Motor Company told Albert Jesser, an employee of Cornelius, that "[i]f General Motors and Chrysler do not control their exhaust, we can do nothing and be competitive" (Tr. XIX, p. 148). Mr. Gay also stated that if the entire package would cost more than $5, Ford would not be interested (Tr. Vol XIX, also at p. 148).

Several other approaches to the automotive pollutant emissions problem have apparently received little interest from the automotive manufacturers. Phillip S. Osborne of Raymond G. Osborne Laboratories developed and patented in the early 1960's preinduction smog control concept which effectively reduced hydrocarbons, carbon monoxide, and oxides of nitrogen (Tr. XI, p. 29). The estimated manufacturing cost of the Osborne device was about $15, (Tr. Vol. XI, p. 39). Again, the automobile manufacturers exhibited little interest in this approach (Tr. Vol. XI. p. 31; Tr. Vol. XII. pp. 14, 16, 24), and what interest was shown by the Ford Motor Company was coupled with indications that Ford would try to circumvent Osborne's proprietary position if the concept proved effective (Tr. Vol. XI, pp. 28–31; Tr. Vol. XII, pp. 10, 21).

Mr. Leslie Fox of S C Carburetor, Inc., developed and patented in the late 1950's and early '60's a unique carburetor which effectively reduced hydrocarbons, carbon monoxide, and oxides of nitrogen while also eliminating evaporative losses, at a manufacturer's cost of about $6. (Tr. Vol. XXXIV, pp. 7–9, 13–14, 19). The automobile manufacturers have shown little or no interest in this device. (Tr. Vol, XXXIV, pp. 16, 21–22).

In sum, although various approaches to the motor vehicle pollutant emissions problem have shown considerable promise, the automobile companies apparently have done little with them. It seems likely that the reason for this attitude is the fact that the AMA cross-licensing agreement placed the automobile producers in a position where they did not have to fear that a competitor would develop an effective device or system for its exclusive use which might become required equipment and thus put the others at a competitive disadvantage.

BOYCOTT

As to the alleged agreement not to purchase or utilize any device developed by a non-signatory to the cross-licensing agreement:

The automobile companies, through AMA, announced in March, 1964 that a target date had been set for the installation of pollution control devices on 1967 model automobilies. The MVPCB of California then approved four devices developed by independent manufacturers (American Machine and Foundry Company—Chromalloy; Universay Oil Products—Arvin Industries; W. R. Grace & Company—Norris-Thermador Corporation: American Cyanamid Company—Walker Manufacturing Company) which, under California law, made the installation of pollution control equipment mandatory on 1966 production. Instead of utilizing any of the approved devices, all auto companies utilized devices or systems which they themselves developed.

Dr. Askew, a member of the MVPCB since its inception, testified that the systems utilized by the industry in 1966 and 1967 did a better job than the catalytic devices approved by the board. He stated further that while the board was not satisfied with these catalytic devices, it approved them and thereby forced the industry to put on its own systems. Thus the California board's approval of these devices was calculated to and did put pressure on Detroit in order to force them to install pollution control equipment. (Tr. Vol. XXXVIII, pp. 16–17).

While it is true that all of the automobile companies use systems developed by themselves, we do ont think that any inference of a boycott can be drawn from

this circumstance. From the standpoint of simplicity and performance these systems at least compare favorably with the devices developed by independent manufacturers. From the standpoint of cost, too, these internally developed systems compare favorably. (Fisher, Tr. Vol. XXXXIV, p. 44). Even assuming that testimony could be developed which would justify a conclusion that the independent devices were better (and cheaper) than the systems utilized, we still believe we would need more direct evidence of an agreement among the auto companies to establish a boycott.

Nor do we believe that the evidence warrants the conclusion that the independent device manufacturers did not know long before the middle of 1964 that the auto companies possessed capability to solve the problem. AMF-Chromalloy developed perhaps the best of the four independent devices mentioned above. In a letter to the MVPCB dated October 29, 1964, Lipchik of Chromalloy stated that the auto companies "have no intention of using the AMF/Chromalloy device" or any of the other independent devices approved by the board. (Tr. Vol. XVI, pp. 84–85).

This conclusion was based on reports received from his men in the field. The specific conversation with an industry representative upon which this statement is most likely based took place on June 24, 1964 between Chandler of Ford and Ulyate of AMF.

Ulyate testified in this regard as follows:

"A. I felt that he said in general Ford would not use anybody's device, particularly ours." (Tr. Vol. XIII, p. 58).

Although Ulyate does not recall Chandler saying so, he received the impression from Chandler that neither Ford nor any other company would buy the AMF device. (Tr. Vol. XVI, p. 125).

This impression was strengthened by other observations contained in a trip report Ulyate made to Lipchik after a June 24–27, 1964 visit to Detroit, which reads in pertinent part as follows:

"In general Ford personnel not very receptive to device concept. They indicated that they doubted any device would ever be installed on a Ford car.

"My impression was that they were just going through the motions in even considering an evaluation. With their attitude, I don't see how they can give a fair evaluation to the burner." (GJ Ex. 171).

Mr. Van Derveer testified, however, that American Motors was seriously considering using the AMF device (Tr. Vol. XVI, p. 116), but that it could not have been engineered into American's production in 1966. (Tr. Vol. XXXXVI, p. 133). After an extensive evaluation, Van Derveer stated, AMF "fell flat on their face." (Tr. Vol. XXXXV, p. 151). Van Derveer also testified that after an evaluation of the Norris and Walker devices it was determined that they were inadequate for American Motors 1966 needs. (Tr. Vol. XXXXV, pp. 151–155). As to the four approved devices, Van Derveer testified that UOP would not "have any part of" American Motors (Tr. Vol. XXXXV, p. 155).

Ervin C. Lenz, Manager, Advanced Development and Smog Engineering, Walker Manufacturing Company, testified that as far back as 1960 the automobile companies made it clear that they were interested primarily in their own systems; that the only time they would utilize an independent device was if either their own systems would not work or if the independent device was better or cheaper. Lenz further testified that it was the hope of manufacturing a better and cheaper device that kept Walker working in the air pollution control field, so as not to lose its position as a supplier of mufflers to the automobile industry. (Tr. Vol. XXVI, p. 93).

Ward B. Sanford, Manager, Ceramics Project, 3M Company, testified that his company was told by General Motors in early 1962 that the engine modification approach was more practical and a better potential answer to the emissions problems than were the socalled tack on devices. (Tr. Vol. XIX, pp. 67–68).

Grand Jury Exhibit Number 421, dated April 25, 1969, a TRW document, which reads in pertinent part as follows, throws further light on GM's attitude: "The job of emission should eventually be controlled in the engine, and some engines are nearly good enough now."

Grand Jury Exhibit Number 422, dated June 9, 1961, a TRW document, also states in pertinent part as follows:

"Chayne of General Motors has informed Mr. Riley that their attempts to solve the problem in a different way probably at the engine, have had considerable success, and they expect this work to be completed in a month or so, and would inform TRW of the results at the proper time. Ergo, General Motors is not very interested in regenerative direct flame afterburners."

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In September, 1963 Chrysler told AMF that its Cleaner-Air-Package would solve the problem for them. (Tr. Vol. XVI, p. 62). Chrysler even submitted its CAP to the MVPCB for approval in July, 1963. Approval of the CAP system was not, however, forthcoming from the board until late in November, 1964.

The underscored portion of the following quotation indicates that as of March 9, 1964, AMA felt that the catalytic devices approved by the MVPCB would not be used by the automobile manufacturers. Grand Jury Exhibit 402, an AMA document quoted in part, *supra*, at p. 42, states further in pertinent part as follows:

"It would be very much to our advantage to avoid this topic—shrug it off or ignore it—for a month or two. *In the interim a lot of things might change in the picture, including even the withdrawal of the catalytic devices now on tests when the submittors analyze the future possibilities for themselves.*" (Emphasis added.)

It is apparent, also, that AMA's activities were designed to discourage independent manufacturers from proceeding with certification, as is evidenced by the reaction of persons connected with independent concerns. In a report dated May 26, 1964, Mr. D. A. Hirschler of the Ethyl Corporation wrote as follows concerning his contacts with AMA:

"With the present likelihood that competitive exhaust devices may be approved in June and our own device late in 1964, all of the automobile manufacturers are making major efforts to find alternate mechanical routes to emission reduction for use in 1967 models, to forestall the mandatory use of the approved exhaust devices. The current thinking is that with this work in progress, no manufacturer of an approved device is likely to make his device available for a possible one-year market on 1966 models." (GJ Ex. 223).

Grand Jury Exhibit Number 418, dated May 21, 1959, a TRW, Inc. document also quoted in part, *supra*, at p. 46, states further in pertinent part as follows:

"Mr. Chandler asked that he be given some time in which to explore this subject among the AMA. He explained that the smog working group, of which he is Vice Chairman, reports directly to the Board of the AMA, which includes Mr. Ford, Mr. Curtice and Mr. Colbert among its members. He implied that few people in the automobile industry appreciated the problem. One function of the AMA working group, he said, had been to 'contain' the problem. His own view was that the smog problem is not bad enough to warrant the enormous cost and administrative problems of installing three-million afterburners."

Dr. Stuart L. Ridgway, formerly senior staff member of the research laboratory of Ramo-Woolridge, a division of TRW, Inc., characterized Chandler's attitude as one seeking to delay the development and installation of anti-smog devices. (Tr. Vol. XXIV, p. 74). Ridgway further testified that the automobile companies acted "in concert." "They acted together and they were all working the same way." (Tr. Vol. XXIV, p. 75).

Ridgway's further testimony was as follows:

"A. What I can distill from a collection of instances, no single one of which I can refer to, was that they were cooperative in making sure that no device was forced upon the automobile industry that would compromise the vehicle. This is the language; this is their position. In other words, they would like to see the problem go away and they stated again and again in all these discussions if there was a device and it was cheap enough and it didn't compromise the vehicle in any way and had no hazards they would be right up front, but what they had done collectively, you know, was to organize to make sure that all of these criteria, performances, of no compromise to the vehicle, of safety, any reasonable criteria that could be put up, cost, these barriers they were cooperating in. They were acting in concert. They made organizations whose purpose was to do these things. They spent money, lots and lots of money on instrumentation, on test tracks, on environmental places, dynamometers, to see whether the afterburner would work when the temperature was 120 degrees Fahrenheit in a driving rainstorm." (Tr. Vol. XXIV, p. 77).

Ridgway also testified as follows on the meaning of "contain" the problem as attributed to Mr. Chandler:

"A. Well, no, I got the—the attitude was . . . here was an attitude: I don't know whether it was wholly Chandler's, but between Chandler and Gay, they said that they spent lots and lots of money in the development of deceleration devices, because it was believed that deceleration was 'the' problem.

"And so, everybody had a deceleration device, and, lo and behold, it turns out that deceleration wasn't the problem. So, they had spent all this money for nothing.

"So, therefore, they had been burned. And they were going to make absolutely sure, first, that the problem was really well understood, and that no device that would cause any detriment to the performance of the car, or anything, would be forced down their throats.

"So, it was clear that, from their point of view, this thing was a defensive organization." (Tr. Vol. XXIII, p. 24).

As to an agreement among the signatories to the cross-licensing agreement to eliminate the competition of third parties in the development of motor vehicle air pollution control equipment, the evidence is as follows:

Dr. Ridgway testified that Woodrow F. Gaines, also a TRW employee, told him that a Ford executive (Gaines' stepfather) reported that GM had, in 1961, increased its valve purchases from TRW by 25% in return for TRW going "slow" on development of its pollution control device. (Tr. Vol. XXIII, pp. 50–56; Tr. Vol. XXIV, p. 327). Mr. Gaines, now employed by the Missile Division, Chrysler Corporation, testified that the source of this report was anot r TRW employee, a technician in the automotive research lab, whose name he could not recall, and that he was not a Ford executive.[10] (Tr. Vol. XXXIII, pp. 13–15). He also testified that as the story originally came to him, the increase in orders was for pistons, not valves, and the increase was in payment of patent rights purchased by GM from TRW. (Tr. Vol. XXXIII, pp. 10–11).

In response to our additional subpoena *duces tecum*, TRW supplied us with the numbers of units and dollar amounts of sales to GM for valves and pistons for the years 1959, 1960, and 1961. Taking 1959 as the base year, GM's valve purchases from TRW increased by approximately 19% in 1960, and declined by a minimal amount in 1961. In 1959, GM purchased no pistons from TRW. In 1960, GM purchased $8,540 worth. In 1961 the amount purchased was $250,321. Total industry passenger car sales in the United States in 1960 were approximately 19% ahead of 1959 sales, and 1961 sales were a minimal amount below the 1959 sales. It is apparent that the GM increase in valve purchases from TRW in 1960 can rationally be accounted for by a rising sales increase. It is further apparent that the 1961 valve purchases followed industry sales closely. At the same time, from 1959 to 1961, GM's share of the market increased from 45.7% to 49.3%. One might even have experienced that value purchases from TRW would have increased. As for the increase in piston sales by TRW to GM in 1961, the total sales figure of $250,321 seems much too low a "compensation" for TRW to go slow on a program in which they had spent approximately $1 million.

Additional witnesses from TRW were called before the grand jury but shed no light on any pressures applied to TRW by automobile companies in this field which are based upon TRW's position as a supplier of products to the automobile industry. Thus we have not developed evidence that any signatory to the cross-licensing agreement attempted in any way to interfere with the efforts of any of the four independent device manufacturers in developing pollution control equipment, whether or not such persons were suppliers of products to the automobile industry. Moreover, the evidence does not show that the industry announcement of the 1967 target date and subsequent utilization of their own systems on 1966 models was a concerted effort by them to boycott the devices approved by the MVPCB of California.

As a matter of fact, continued work in the air pollution control equipment field by outside concerns has been prompted by encouragement from the automobile industry. Mr. M. F. Venema, President and Chairman of the Board of Directors of Universal Oil Products Company, (UOP), testified that General Motors told them that they will need a device in addition to their air injection systems in order to meet future criteria. (Tr. Vol. XXXIX, p. 44). UOP is now supplying GM with catalysts. (Tr. Vol. XXXIX, p. 43). Venema stated that the industry's attitude is much better today than it was years ago in that the industry now feels it can gain from outsiders as compared to "thei eling a few years back that the outsiders were more intruders than helpers." r. Vol. XXXIX, p. 43).

With respect to various aspects of the entire situation under investigation here, some significant admissions by John D. Caplan, head of the Fuels and Lubricants Department, General Motors Corporation, and former Chairman of the VCP, are contained in Grand Jury Exhibit Number 491, dated December 9, 1965. Mr. Caplan's remarks are in response to a request by Louis C. Lundstrom, Director, Automotive Safety Engineering, GM, for Caplan's review of and comments on Chapter 4 of the book entitled "Unsafe at Any Speed" by Ralph Nader. Chapter 4 deals by stating that "you will note that I have not limited my review only to criticisms

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Footnotes at end of article.

of the chapter but have also acknowledged areas wherein Nader's comments may be valid." (Tr. Vol. XXXV, p. 55; GJ Ex. 491). Referring to specific pages of the book, Caplan made *inter alia* the following comments:

Page 101: "(a) The million dollar a year industry expenditure cited on this page is optimistically high for the 1953 era. . . . (GJ Ex. 491, p. 3; Tr. Vol. XXXV, p. 55)."

Page 105: "Nader's statement that the California MVPCB action in certifying the four devices 'moved' the automobile industry management to up the target date from the 1967 to the 1966 model year appears valid. However, he fails to point out that this could be done only after the MVPCB cooperated to the extent of allowing exemptions for the 1966 model year on many engine-transmission combinations." [11] (GJ Ex. 491, pp. 3–4; Tr. Vol. XXV, p. 56).

Page 106: "(a) The comment that the industry was guilty of 'only speaking with one voice' in the automobile air pollution area is true. Although individual company technical personnel were allowed to present 'company' technical papers, essentially all other types of pronouncements emanated only from AMA statements." (GJ Ex. 491, p. 4; Tr. Vol. XXXV, p. 56).

Page 107: "Mr. Nader's remarks concerning the basic issue (paragraph 3) appear to be the crux of this chapter. His criticism of the lack of recognition of the problem and lack of work on the problem by the industry is easily refuted. Where we must give the 'devil his due' is in the area of implementation of our findings. Does such implementation occur only in response to legislative pressure and public criticism? Development of material to refute this criticism is difficult" (GJ Ex. 491, p. 4; Tr. Vol. XXV, p. 57).

FOOTNOTES

[1] Mountains surround the Los Angeles basin on three sides with but one outlet to the ocean. This basin also has a unique condition called temperature inversion. Ordinarily the air becomes cooler the higher it rises. In the Los Angeles area, during inversion periods, the polluted air is trapped beneath an invisible ceiling of warmer air thus preventing the normal upward flow of air pollutants to a level where it would be dissipated or diluted. Thus a concentration of air pollutants occurs to varying degrees, depending on the height of the inversion lid. Too, in this area, weak winds prevail which at times stagnate completely, lacking the velocity to blow the pollution rapidly out of the basin, thus giving the abundant sunshine of southern California ample time to produce the photochemical reactions between the pollutants more fully defined herein as "smog."

[2] Los Angeles County has the highest registration of cars per person (2.3 persons/car) of any county in the United States.

[3] As late as July 30, 1963 Motor Vehicle Pollution Control Board (MVPCB) officials visiting Detroit were told: "based on the time that it takes to develop any new innovation in motor car design, the solution of the smog problem by the automobile industry was probably 7 to 10 years away . . ." (Tr. Vol. XXXVIII, pp. 7–9; GJ Ex. 227). As herein after shown, the industry was able to and did install exhaust systems or devices in late 1965 on 1966 models when forced to do so.

[4] AMA now employs a full-time president. (Tr. Vol. XVIII, pp. 54–55; GJ Ex. 300).

[5] The cross-licensing agreement provides as follows:

"ARTICLE V—EXCHANGE OF TECHNICAL DATA AND INFORMATION

"Each of the parties hereto further agrees to exchange through its authorized representative with representatives of the remaining parties hereto all technical data and other information pertaining to said Licensed Devices. Such exchange of technical data and other information shall be conducted under the direction of the Vehicle Combustion Products Subcommittee of the Engineering Advisory Committee of the Automobile Manufacturers Association." (GJ Ex. 263, 264, 265, and 266).

[6] The significance of the AMA Suggestion Submission Agreement is illustrated by the following pertinent excerpts from a letter of October 7, 1960 written by R. H. Isbrandt, Director, Automotive Engineering, American Motors Corporation:

As explained in our meeting on September 21st, the automotive companies, working through the Automobile Manufactures Association, have agreed that the treatment of exhaust gas is an industry problem which will be handled on a cooperative basis. The A.M.A. Submission Agreement was developed to be used by all automobile companies in evaluating exhaust devices which are submitted for test. This assures that there will be an interchange of information between the automobile companies and that no one company will attempt to take competitive advantage of any solution which is developed in our current test program. *For this reason we have requested that you sign the A.M.A. Submission Agreement.* Other suppliers, including chemical manufacturers have signed this agreement recognizing that there is no desire on the part of any automobile company to do anything that would be detrimental to any supplier who can come up with a solution to this problem.' (GJ Ex. 534).

[7] When an attempt was made in 1963 to broaden the scope of the cross-licensing agreement "to overcome the restrictions that are currently preventing adequate discussion of technical steps that will lead to solutions (GJ Ex. 305) the attempt was defeated by the opposition of GM. This is explained in a GM internal communication from H. F. Barr, its member on the EAC, dated May 6, 1965, "Subject: G.M. Policy on A.M.A. Vehicle Combustion Products Com. Work" as follows:

"2. In an endeavor to permit technical discussion, the Engineering Advisory Committee of A.M.A. asked the A.M.A. Patent Committee to propose broader language for the agreement.

* * * * * * *

"3. In subsequent review of the proposed action for the A.M.A. Board of Directors, in our Engineering Policy Group meeting of March 20, 1963, our management reaffirmed that the A.M.A. agreement should not be changed in this way. On April 30, the E.A.C. further discussed this proposal, with G.M. being the only member opposed to extending the agreement to other areas.

"4. The basic trouble with this problem is the involvement of (1) an established cross licensing agreement for hardware now established, with (2) a need for technical discussion and exchange of information in broader areas. We feel that these are two separate items and need not be combined in a new, broader cross licensing agreement for non-existent hardware." (GJ Ex. 325).

[8] The fact that on occasions the pcv was offered as optional equipment indicates the ability to supply this air pollution control equipment, yet the auto manufacturers did not install them on all models quite evidently because of the agreement previously referred to.

[9] This illustrates that bar an agreement, competition to research, develop and manufacture pollution control devices would stimulate and compel rather than delay the installation of devices by all companies. (Tr. Vol. XXX, p. 147).

[10] The testimony was that this technician was known as Olie. We called TRW an official named Ohly as a witness, but ascertained that he was not the person involved. We have learned since the last grand jury session that the person involved is Merle E. Olson of Chesterland, Ohio. From our experience in this matter, however, we doubt that his testimony will be helpful.

[11] California State regulations permitted only 2% exemptions. At almost less than 4% were exempted (Askew, Tr. Vol. XXXVIII, p. 22).

[From the Congressional Record, Sept. 3, 1969]

CONGRESSMEN URGE OPEN TRIAL IN SMOG CONTROL ANTITRUST CASE

(Mr. BROWN of California asked and was given permission to address the House for 1 minute, to revise and extend his remarks and include extraneous matter.)

Mr. BROWN of California. Mr. Speaker, it is futile to try to compromise the quality of our environment. Yet, that is just what will happen if the Justice Department is pressured into allowing a consent decree to be issued in the pending antitrust suit against automobile manufacturers who are charged with conspiring to prevent speedy development and installation of antismog devices.

Today, I have joined with 18 of my colleagues in the House in sending to Attorney General Mitchell a letter requesting that an open trial be held in this vital case. Pretrial discussions have been underway for some time, and it is possible a decision on whether to hold a trial or go to decree might be made any day now.

Intense lobbying being applied by the Washington counsel for the Automobile Manufacturers Association—AMA is one of the defendants along with the four major car makers—aims to have the Justice Department agree to a nolo contendere plea, and then have the Department put out a consent decree. Such a consent judgment admits no liability for the alleged charges, and so it becomes nothing more than a slight tap on the wrist for the manufacturers.

We believe this case is one of the most vital suits ever instituted by the Justice Department, and we see it representing a major forward step in the campaign for effective air pollution abatement. It must not be nullified or circumvented.

Mr. Speaker, at this point, I would like to insert into the RECORD copies of the letters—my initial letter sent last week, and the letter signed by my 18 colleagues—which were sent to the Justice Department:

HOUSE OF REPRESENTATIVES,
Washington, D.C., August 29, 1969.

Hon. JOHN N. MITCHELL,
Attorney General of the United States,
Washington, D.C.

DEAR MR. ATTORNEY GENERAL: Over the last twenty years, Southern California residents have been subjected to ever-increasing amounts of air pollutants at a rate which seriously threatens both human health and the complete delicate ecology of the area. Although vigorous efforts by state, local and Federal officials have succeeded in reducing many of the major polluting factors, a prime cause of this air pollution continues to be motor vehicle exhaust emissions.

As the problem grew more dangerous, numerous government officials at all levels pressed automobile manufacturers to develop and produce effective anti-smog engines and control devices. But, generally, response from manufacturers has been disappointing. In a letter to President Johnson, Los Angeles County Supervisor Kenneth Hahn noted in 1965 that "Now, after twelve years of correspondence . . . I have found out that you cannot 'cooperate' or urge them 'voluntarily' to do the job."

The Justice Department's anti-trust suit now pending against the manufacturers and the Automobile Manufacturers Association represents a crucial forward step in the drive for effective air pollution abatement. The cost to the American public—in terms of ill health and environmental damage—resulting from the alleged collusion has been huge.

It is my understanding that pre-trial negotiations are now underway between Justice Department and the defendants, and that chances are good that a consent judgment may be reached in this case and that there would then be no open trial.

I believe that the overriding significance of this case makes it imperative that an open trial be held, and I urge you to push for such a trial. The alleged actions of the defendants are—if true—reprehensible, and full and complete public knowledge of them should be brought before the public. I do not feel that the public interest in served in this case by closed-door negotiations.

I am also worried that a plea of nolo contendere and a consent judgment would leave many municipalities and other government units who are closely following this case without sufficient legal grounds to institute damage suits.

In addition, the case offers the opportunity to rule on some important precedents. The question of joint responses by a manufacturers association plays a key role in this case, and the Justice Department's prayer is potentially a landmark position. Another area is that of product fixing to limit competition, and I would hope that the full force of the law is brought to bear in order to deter this sort of collusion.

I fully believe that this case may be one of the most vital suits ever instituted by the Justice Department, and again I urge you to do all you can to hold an open trial.

Sincerely,

GEORGE E. BROWN, Jr.,
Member of Congress.

HOUSE OF REPRESENTATIVES,
Washington, D.C., September 2, 1969.

Hon. JOHN N. MITCHELL,
Department of Justice,
Washington, D.C.

DEAR MR. MITCHELL: We are writing to indicate our concern over the persistent and disquieting reports that the Department of Justice is about to compromise one of the most important antitrust cases affecting the health and welfare of the American people. We are aware of the closed-door negotiations now taking place between the automobile industry's lobbyists and the Department, negotiations which may lead to a consent decree in the Department's case against the Automobile Manufacturers Association (AMA), General Motors, Ford, Chrysler and American Motors.

Earlier this year, your predecessors in the Department resisted extraordinary industry pressures and filed a civil complaint against the defendants—(although the Department did decline to ask for a criminal indictment, as its investigating attorney had requested). The complaint alleges generally that the automobile companies, operating under the auspices of the AMA, joined together, through the device of a cross-licensing agreement—to suppress research, development and application of pollution control devices. The more important allegations charges that the companies agreed to pursue research, development, manufacture and installation of pollution control devices on a non-competitive basis, that they agreed to seek joint appraisal of patents submitted by persons not a party to the cross-licensing agreement, and that they agreed on at least three occasions—in 1961, 1962, and 1964—to attempt to delay installation of motor vehicle air pollution control equipment.

These allegations, if proved true, mean that the defendants bear responsibility for a great share of the injury to human health and the many millions of dollars in economic injury resulting from automobile pollution. If these charges are true, the American people have a right to be fully informed of this outrageous corporate callousness by a full and open trial of the issues involved. We fear, however, that the American people will be denied their right to know the full story. We fear that the entire incident will be covered over by a legal deal arranged between the Department and the AMA's Washington counsel.

The representations made to your Department by this law firm do not include, we are sure, the following information:

That the automobile is responsible for dumping more than 90 million tons of polluants into the atmosphere each year, more than twice as much as any other single pollutor.

That the automobile accounts for 91% of all carbon monoxide, 63% of the unburned hydrocarbons and 48% of the oxides of nitrogen emitted from all sources.

That doctors, in a single year, advised 10,000 people to move away from Los Angeles because of the harmful effects of air pollution. (Automobile pollution represents 85% of the contaminants emitted into the ambient air of Los Angeles daily).

That air pollution—of which motor vehicles account for approximately 50% nationally—contains serious toxic substances associated with higher rates of illness and mortality from emphysema, long cancer, chronic bronchitis and heart diseases.

Professor Barry Commoner, leading authority on pollution, said just last week:

"Once the automobile is allowed out of the factory and transformed, it then reveals itself as an agent which has rendered urban air carcinogenic, burdened human bodies with nearly toxic levels of carbon monoxide and lead, embedded pathogenic particles of asbestos in human lungs, and contributed significantly to the pollution of surface waters."

The time remaining for us to return our environment to a livable state is short, and if the allegations contained in the Department's complaints are proved true, the automobile companies have deliberately and cynically wasted fifteen precious years. The Los Angeles County Board of Supervisors has charged that if the automobile companies had sincerely devoted their energies to the air pollution problem in California during the years 1953–1956, "air pollution from automobiles would have ceased to be a problem by 1966 . . ."

If the defendants in this case are indeed culpable, a consent decree of almost any kind would undermine the penalties of the antitrust laws designed to deter future adventures into collusion. There would be no public acknowledgement by a public-relations conscious industry of its responsibility for the appallingly slow progress in air pollution control. Furthermore, a consent decree would raise formidable barriers to the many treble damage suits which could be founded on an open trial and full public record of the defendants' activities.

Many municipalities are closely following this case with a view toward bringing followup actions for pollution damage to health, property and local economies, much in the same way that states and municipalities brought follow-up suits in the *Library Book Cases*. Then also, there are a number of businessmen who invested large sums in pollution-control research, many of whom claim that they were injured by the AMA agreement. Furthermore, it is conceivable that this would open up a new area for class actions to be brought on behalf of thousands of people. But a consent decree might mean that the thousands of pages of evidence—collected by federal investigators over the course of a two-year study at a cost of many thousands of dollars—would be left to collect dust in the Department's file, forever lost to private litigants. This, of course, is what the auto industry wants. We hope that the Department does not become an accomplice in the industry's attempt to avoid redressing the injuries which it may have caused.

In addition, a consent decree would mean that the Department is surrendering a unique opportunity in a particularly strong case to have the courts rule on important landmark legal questions. For one, the Department's complaint requests that the AMA be restrained from making joint responses to government regulatory agencies with regard to information concerning air pollution control technology. Should the Department prevail on this question in court, it would do much to make public any diversity of opinion which may exist among automobile manufacturers in the field of air pollution control. In addition, the Department would have a new weapon in its arsenal to loosen the death-grip which many trade associations hold over weaker members. Secondly, there is the important issue of "product fixing", the joining together of manufacturers to limit competition for product quality. Until recently, the main thrust of antitrust law enforcement has generally been limited to price fixing and a ruling on product fixing might deter a practice which is all too common in many American industries.

If the defendants have broken the antitrust laws, and are responsible for the adverse health and economic effects of automotive pollution, then they must

be prepared to have the law applied with its full force. The Administration promised to see that the rights of victims would be protected along with the rights of law-violators. In this situation, an open public trial would help show that this Administration considers corporate lawlessness on no different footing than any other violation of law.

Sincerely,

John A. Blatnik, George Brown, Phillip Burton, Shirley Chisholm, John Conyers, Jr., Bob Eckhardt. Don Edwards, Leonard Farbstein, Donald Fraser, Andrew Jacobs, Joseph Karth, Edward Koch, Allard Lowenstein, Richard Ottinger, Betram Podell, Benjamin Rosenthal, Edward Roybal, Robert Tiernan, Charles Wilson.

Next, and because it is such an important suit, I shall insert a copy of the Justice Department's complaint against the manufacturers:

[U.S. District Court, Central District of California, Civil No. 69-75-JWC, Filed January 10, 1969]

UNITED STATES OF AMERICA, PLAINTIFF, v. AUTOMOBILE MANUFACTURERS ASSOCIATION, INC.; GENERAL MOTORS CORPORATION; FORD MOTOR COMPANY; CHRYSLER CORPORATION; AND AMERICAN MOTORS CORPORATION, DEFENDANTS

COMPLAINT

The United States of America, plaintiff, by its attorneys, acting under the direction of the Attorney General of the United States, brings this civil action against the defendants named herein, and complains and alleges as follows:

I

Jurisdiction and Venue

1. This complaint is filed and these proceedings are instituted under Section 4 of the Act of Congress of July 2, 1890, as amended. (15 U.S.C. § 4), commonly known as the Sherman Act, in order to prevent and restrain continuing violation by the defendants, as hereinafter alleged, of Section 1 of the Sherman Act.

2. Each of the corporate defendants named herein transacts business and is found within the Central District of California.

II

Defendants

3. Automobile Manufacturers Association, Inc., a corporation organized and existing under the laws of the State of New York with its principal place of business in Detroit, Michigan, is made a defendant herein. Automobile Manufacturers Association, Inc., is a trade association whose membership consists mainly of firms engaged in the business of manufacturing and selling motor vehicles and component parts and accessories thereto in various states of the United States.

4. The Corporations named below are made defendants herein. Each of said corporations is org nized and exists under the laws of the State indicated and has its principal place of business in the city indicated. Within the period of time covered by this complaint said defendants have primarily engaged in the business of manufacturing and selling motor vehicles in various states of the United States, and also manufacture and sell component parts and accessories thereto.

Defendant corporation, General Motors Corporation; State of incorporation, Delaware; principal place of business, Detroit, Michigan.

Defendant corporation, Ford Motor Company; State of incorporation, Delaware; principal place of business, Dearborn, Michigan.

Defendant corporation, Chrysler Corporation; State of incorporation, Delaware; principal place of business, Highland Park, Michigan.

Defendant corporation, American Motors Corporation; State of incorporation, Maryland; principal place of business, Detroit, Michigan.

5. Whenever in this complaint reference is made to any act, deed or transaction of a corporate defendant, such allegation shall be deemed to mean that said

corporation engaged in said act, deed or transaction by or through its officers, directors, agents or employees while they were actively engaged in the management, direction or control of corporate business affairs.

III

Co-conspirators

6. Each of the corporations listed below in this paragraph is not named a defendant herein but is named as a co-conspirator and has participated as a co-conspirator with the defendants in the offense hereinafter charged and has performed acts and made statements in furtherance thereof.

Corporation, Checker Motor Corporation (successor to Checker Cab Manufacturing Corporation); State of incorporation, New Jersey; principal place of business, Kalamazoo, Michigan.

Corporation, Diamond T Motor Car Company; State of incorporation, Illinois; principal place of business, Cleveland, Ohio.

Corporation, International Harvester Company (a consolidation of International Harvester Company, a New Jersey Corporation, and International Harvester Corporation, a Delaware Corporation); State of incorporation, Delaware; principal place of business, Chicago, Illinois.

Corporation, Studebaker Corporation (successor to Studebaker-Packard Corporation); State of incorporation, Michigan; principal place of business, South Bend, Indiana.

Corporation, White Motor Corporation (successor to The White Motor Company); State of incorporation, Ohio; principal place of business, Cleveland, Ohio.

Corporation, Kaiser Jeep Corporation (successor Willys Motors, Inc., a Pennsylvania Corporation); State of incorporation, Nevada; principal place of business, Oakland, California.

Corporation, Mack Trucks, Inc. (successor to Back Manufacturing Corporation): State of incorporation, New York; principal place of business, New York.

7. Various other persons, firms and corporations not made defendants herein have participated as co-conspirators with the defendants in the offensive charged in this complaint and have performed acts and made statements in furtherance thereof.

IV

Definition

8. As used herein, the term "motor vehicle air pollution control equipment" means equipment, or any part thereof, designed for installation on a motor vehicle or any system or engine modification on a motor vehicle which is designed to cause a reduction of pollutants emitted from the vehicle, including, but not limited to, any device for the control of emissions of pollutants from the exhaust system, the crankcase, the carburetor, or the fuel tank.

V

Trade and commerce

9. Automobiles for the most part are manufactured in the State of Michigan and are shipped therefrom to each of the fifty states of the United States. Some automobiles are assembled in various states of the United States from parts manufactured in the State of Michigan and other states. In 1966, 78,315,000 passenger cars and 15,864,000 trucks and buses, exclusive of off-the-road vehicles, were registered in the United States. In that year, 8,604,712 passenger cars valued at more than $17½ billion and 1,791,587 commercial vehicles valued at more than $3.9 billion were produced in this country. Of the trucks produced, 96,560 were built with diesel motors.

10. The largest number of passenger cars registered and new cars sold in any state of the United States in 1966 was in the State of California where 7,621,792 cars were registered and 832,338 new cars sold. The largest number of passenger cars, registered in any county of any state in the United States in 1966 was in Los Angeles County where 2,932,980 cars were registered. Similarly, in 1966 California accounted for the largest number of truck registrations and new truck sales with 1,542,984 trucks registered and 150,927 new trucks sold, and Los An-

geles County accounted for the largest number of trucks registered, numbering 436,218.

11. Since at least 1952 it has been established that motor vehicles contribute to air pollution by the emission of hydrocarbons, carbon monoxide, oxides of nitrogen and other contaminants. For example, in Los Angeles County, as of January 1967, gasoline-powered motor vehicles accounted for 12,465 tons out of a total of 14,610 tons, or 85.3 percent of contaminants emitted into the ambient air daily. As a result of new and continuing requirements that automotive vehicles be equipped with air pollution control devices, a large and growing market for the production and installation of such devices has developed. Motor vehicle air pollution control devices are shipped in interstate commerce either as engine or system modifications or as equipment attached to automobiles, which are shipped from Michigan and other states to each of the fifty states of the United States.

VI

Offense alleged

12. Beginning at least as early as 1953, and continuing thereafter up to and including the date of this complaint, the defendants and co-conspirators have been engaged in a combination and conspiracy in unreasonable restraint of the aforesaid interstate trade and commerce in motor vehicle air pollution control equipment in violation of Section 1 of the Sherman Act (15 U.S.C. § 1).

13. The aforesaid combination and conspiracy has consisted in a continuing agreement, understanding, and concert of action among the defendants and co-conspirators, the substantial terms of which have been and are:

(a) to eliminate all competition among themselves in the research, development, manufacture and installation of motor vehicle air pollution control equipment; and

(b) to eliminate competition in the purchase of patents and patent rights from other parties covering motor vehicle air pollution control equipment.

14. For the purpose of forming and effectuating the aforesaid combination and conspiracy, the defendants and co-conspirators did those things which they combined and conspired to do, including, among other things, the following:

(a) agreed that all industry efforts directed at the research, development, manufacture and installation of motor vehicle air pollution control equipment should be undertaken on a non-competitive basis;

(b) agreed to seek joint appraisal of patents and patent rights submitted to any of them by persons not parties to a cross-licensing agreement entered into on July 1, 1955, and amended and renewed periodically, and to require "most-favored-purchaser" treatment of all parties to the cross-licensing agreement if any one were licensed by a person not a party to that agreement;

(c) agreed to install motor vehicle air pollution control equipment only upon a uniform date determined by agreement, and subsequently agreed on at least three separate occasions to attempt to delay the installation of motor vehicle air pollution control equipment:

(1) in 1961 the defendants agreed among themselves to delay installation of "positive crankcase ventilation" on vehicles for sale outside of California until the model year 1963, despite the fact that this antipollution device could have been installed nationally for the model year 1962 and that at least some automobile manufacturers expressed willingness to do so, in the absence of a contrary industry-wide agreement;

(2) in late 1962 and extending into 1963, the defendants agreed among themselves to delay installation of an improvement to the positive crankcase ventilation device, an improvement which the California Motor Vehicle Pollution Control Board had indicated it would make mandatory;

(3) in early 1964 the defendants agreed among themselves to attempt to delay the introduction of new exhaust pollution control measures on motor vehicles sold in California until the model year 1967; despite the fact that all were capable of installing the improvement for the model year 1966, the defendants agreed to tell California regulatory officials that installation of exhaust antipollution measures would be technologically impossible before 1967, and only under regulatory pressure made possible by competing device manufacturers not in the automobile industry did the defendants agree to a California regulatory requirement that exhaust devices must be installed for the model year 1966; and

(d) agreed to restrict publicity relating to research and development efforts concerning the motor vehicle air pollution problem.

VII

Effects

15. The aforesaid combination and conspiracy has had, among others, the following effects:

(a) hindering and delaying the research, development, and manufacture—both by the defendants and coconspirators and by others not parties to the agreements alleged herein—and the installation of motor vehicle air pollution control equipment;

(b) restricting and suppressing competition among the defendants and co-conspirators in the research, development, manufacture and installation of motor vehicle air pollution control equipment; and

(c) restricting and suppressing competition in the purchase of patents and patent rights covering motor vehicle air pollution control equipment.

Prayer

Wherefore, the plaintiff prays:

1. That the Court adjudge and decree that the defendants have engaged in a combination and conspiracy, in unreasonable restraint of the aforesaid interstate trade and commerce, in violation of Section 1 of the Sherman Act.

2. That each of the defendants named in this complaint, its successors, assignees and transferees, and the respective officers, directors, agents and employees thereof, and all persons acting or claiming to act on behalf thereof:

(a) be enjoined from continuing, maintaining or renewing, directly or indirectly, the combination or conspiracy hereinbefore alleged, or from engaging in any other practice, plan, program, or device having a similar effect;

(b) be enjoined from entering into any agreements, arrangements, understandings, plan or program with any other person, partnership, or corporation, directly or indirectly:

(1) to delay installation of air pollution control equipment or otherwise restrain individual decisions as to installation dates;

(2) to restrict individual publicity of research and development relating to air pollution control technology;

(3) to require joint assessment of the value of patents or patent rights relating to air pollution control equipment;

(4) to require that acquisition of patent rights relating to air pollution technology be conditioned upon availability of such rights to others upon a most-favored-purchaser basis; or

(5) to respond jointly to requests by government regulatory agencies for information or proposals concerning air pollution control technology unless such agency requests a joint response in a particular case; and

(c) be required to issue to any applicant interested in developing motor vehicle air pollution technology unrestricted, royalty-free licenses and production know-how under all United States patents owned, controlled or applied for to which the cross-licensing agreement dated July 1, 1955, as amended, has been applicable, and to make available to any such applicant all other know-how related to air pollution control technology which has been exchanged with any other defendant.

3. That the plaintiff have such other, further and different relief as the nature of the case may require and the Court may deem just and proper in the premises, including cancellation of the cross-licensing agreement dated July 1, 1955, as amended, and an injunction ensuring that all future joint arrangements relating to air pollution control technology be appropriately limited as to subject matter of joint effort and numbers of participants so as to maintain competition in the development of air pollution technology.

4. That the plaintiff recover the costs of this suit.

RAMSEY CLARK,
Attorney General.
EDWIN M. ZIMMERMAN,
Assistant Attorney General.
BADDIA J. RASHID,
Attorney, Department of Justice.
WM. MATTHEW BYRNE, Jr.,
U.S. Attorney.
RAYMOND W. PHILIPPS,
CHARLES L. MARINACCIO,
Attorneys, Department of Justice.

A few weeks after the suit was filed, Morton Mintz of the Washington Post wrote this interesting background story about the early history of the case:

[From the Washington Post, Jan. 26, 1969]

SMOG FIGHTER INSPIRED AUTO INDUSTRY LAWSUIT

(By Morton Mintz)

More than four years ago, an angry municipal official made a speech in Houston. Little noticed at the time, the speech was the genesis of the Justice Department's civil antitrust suit filed this month charging that the four major U.S. auto manufacturers and their trade association conspired to delay development and installation of devices to curb automotive air pollution.

The public official was S. Smith Griswold, then air pollution control officer of Los Angeles County. For a decade, he had fought to control the sources of smog. All of these sources but one were brought under control or significantly checked. The exception was by far the most important source: the ubiquitous automobile.

As time went on, Griswold became convinced that for all its talk about how hard it was trying and how much it was spending, Detroit was at best halfhearted about control devices for the crankcase and the exhaust system. Finally, in June, 1964, in his Houston speech to the Air Pollution Control Association, he exploded.

"Everything that the industry is able to do today to control auto exhaust was possible technically ten years ago," he said. "No new principles had to be developed; no technological advance was needed; no scientific breakthrough was required."

Griswold depicted Detroit as a citadel of "arrogance and apathy" that has "bought ten years of delay and unhampered freedom to pour millions of tons of toxic contaminants into the atmosphere."

At the time, the industry was spending $1 million a year for pollution control. Griswold contrasted this with the total of $9.5 million that 22 industry executives earned in 1963 and with the $1 billion being spent for 1965 model changes.

Finally, Griswold tried to explain the industry's purported apathy. "Control of air pollution does not make cars easier to sell," he said. Neither does it "make them easier to produce. To people interested in profits, expenditures for the development and production of exhaust controls are liabilities."

A CASE MADE UNWITTINGLY

In an interview, Griswold, who now heads a Washington consultant firm on air pollution and other environmental problems, said he was unaware that his speech laid out the essentials of an antitrust case.

Nothing might have happened had it not been for a chance visit that Ralph Nadar, then an obscure volunteer worker in the Labor Department, paid to the office of Thomas F. Williams, public information officer for the Division of Air Pollution of the Public Health Service.

Donald Green, an aide to Williams, showed the speech to Nader, who as a lawyer sensed its antitrust implications. In a recent interview, Nader said that the Griswold speech struck him as a potentially classic portrayal of "product-fixing"—activity covered by the antitrust laws. In this case, he felt, the activity involved important impacts on health and might be delaying technology that would permit eventual phasing out of the fume-producing internal combustion engine.

After reading the speech, Nader telephoned Griswold in Los Angeles. Several long conversations followed, on the phone and during Griswold's visits to Washington.

Nader tried but failed to interest a Justice Department antitrust lawyer who specialized in auto industry matters. But in the late summer of 1964, Nader learned that William H. Orrick Jr., then the Department's antitrust chief, had set up a new policy planning staff. Nader got in touch with its head, Murray H. Bring.

Neither Bring, now a member of the Washington law firm of Arnold and Porter, nor any past or present Justice Department official involved with the case would discuss it. But the upshot of Nader's getting in touch with Bring was that he was invited to outline his antitrust theory to Orrick and more than a dozen of his aides. At a meeting lasting more than an hour, he recalls, he argued that alleged product-fixing of this kind deserved at least as much priority as conventional price-fixing cases.

In late 1964, Griswold himself informally asked the Department to make an antitrust investigation. Although he told an interviewer he could not be certain from memory, he said he believed he alerted Justice to a resolution that he was helping to prepare for the Los Angles County Board of Supervisors.

ADVISE 10,000 TO MOVE AWAY

As finally adopted by a unanimous vote on Jan. 26, 1965, the resolution traced the history of the problem of air pollution in Los Angeles County, pointed out that because of that problem physicians had advised 10,000 persons to move away in a single year and said that health and welfare continue to be "jeopardized by the exhaust emissions of 3.5 million motor vehicles, burning about 7,150,000 gallons (of gasoline) daily."

The resolution charged that the industry had pooh-poohed the role of automobiles in Los Angeles pollution until forced to change its position by an accumulation of overwhelming evidence, by the spur of competition from "outsider" firms that had developed control devices on their own and by the pressure of California legislation making control devices mandatory.

If the Automobile Manufacturers Associations (AMA) "had given the same attention to the problem in 1953–56 as they did after installation became mandatory, air pollution from motor vehicles would have ceased to be a problem in 1966," the resolution asserted.

Saying that action was not taken in the 1950s because of agreements among Automobile Manufacturers Association members to pool all of their findings and to cross-license developments for pollution control, the Board of Supervisors concluded by requesting the Justice Department to make an antitrust investigation.

By the time the resolution was formally adopted, the Justice Department already had served demands for records on the industry—an action it took in early January, 1965.

Essentially, the Department complaint filed last Jan. 10 in Los Angeles reflects the Board's resolution. The complaint points out, for example, that in the single month of January, 1967, gasoline-powered vehicles dumped 12,465 tons—about 25 million pounds—of contaminants into the atmosphere of the bowl-shaped Los Angeles area. This was 85 per cent of all emissions.

And the suggestions was obivous in the suit that had the defendants competed in the field of control devices, rather than purportedly suppressing progress in violation of the antitrust laws, there would have been less pollution, less disease and less property damage.

The AMA's position is the reverse: the "cooperation" among the defendants—General Motors, Ford, Chrysler and American Motors, plus the AMA—was not only entirely legal and open and aboveboard, but was also the only feasible way to achieve the progress everyone sought.

The Department's charges also were heatedly rejected by the defendant manufacturers. American Motors, for example, said it "categorically denies engaging in any combination or conspiracy . . ."

COLLISION WITH AUTO SAFETY

Between the time the Justice Department started to move on the case and the time the suit was filed, the matter became involved briefly with a congressional hearing.

By late 1965, the industry was faced with another crisis: the seeming inevitability of auto safety legislation. For Detroit, the question was how tough the law would be.

In April, 1966, the AMA went before the Senate Commerce Committee to plead for an "umbrella against antitrust" so that it could undertake joint development of safety devices.

To illustrate the need for the "umbrella," AMA spokesman John S. Bugas. a Ford vice president, pointed out that the industry already was under investigation in connection with pollution control devices.

Committee Chairman Warren G. Magnuson (D-Wash.) asked Justice for immediate comment. Donald F. Turner, who meanwhile has succeeded Orrick as head of the Antitrust Division, replied with a letter attacking the industry proposal. The Department's investigation concerned cooperative efforts "to suppress, not to promote," use of the devices, Turner said. Besides, the antitrust laws are not a barrier to "necessary and constructive" joint efforts, he said.

Turner had assigned the investigation to Samuel Flatow, who has since retired from the Department to enter private practice here. As a result of Flatow's work, first in Washington and then in Los Angeles, a grand jury was convened, in July 1966, and heard evidence until December, 1967. Flatow then requested permission to ask the jurors to return a criminal indictment, a request the Department denied.

There may have been a practical consideration: At least four Federal judges who might have received the case reportedly are strongly opposed to criminal sanctions in antitrust cases. But a more fundamental consideration is that long-standing Department policy reserves the criminal route for price-fixing and other traditional cases in which there is no question of blatantly illegal conduct. The pollution case was not traditional.

Another factor is the practical utility of a criminal case as opposed to a civil case. A criminal case can result in penalties intended in part to deter further misconduct. But a civil case can lead to the fashioning of a court decree that prohibits specific forms of misconduct thereafter.

An Unusual Prayer

In the pending case, the Department offers an unusual "prayer," to use the legal term. It is that the court will prohibit the defendants from responding "jointly to requests by Federal regulatory agencies for information or proposals concerning air pollution control unless such agency requests a joint response in a particular case." This is an uncommon recognition of the proposition that the behavior of trade associations can violate the antitrust laws.

If the "prayer" is granted, one of the broad questions that will be generated is this: When any Government agency is involved in the process of setting safety standards, can a trade association be the spokesman for an industry in which dissent and diversity among member companies is being suppressed?

The Department's "prayer" is, of course, confined to the particular facts of the air pollution case. But the petition is also in accord with the intent of Congress, expressed in the auto safety law, that car manufacturers be stimulated by the National Traffic Safety Agency to compete in the area of safety.

Late last year, the Agency declared its intention to require manufacturers to disclose to new-car buyers such safety-related performance data as the distances needed to brake to a stop from various speeds, data that would permit comparative shopping on safety aspects. The primary response from the industry was the AMA's. GM, Ford and Chrysler filed no initial response of their own. American Motors' was an endorsement of the AMA's.

Nader's contention—denied by the AMA—was that the Association controlled the responses and that the AMA was itself controlled by GM, the industry leader.

The Department also seeks a court order banning patent licensing agreements of the kind used here and for bidding other agreements under which individual car makers did not publicize their progress in pollution control.

Another subtle but important aspect of the case is its origins in a marriage of antitrust lawyers to specialists with expertise in a field as arcane as pollution control devices.

Nader believes that the full potential of the antitrust laws to protect the public against "product-fixing" and technological repression and stagnation cannot be realized until engineers and other experts become part of the regular staff of antitrust agencies.

A prominent Washington antitrust lawyer with both private and Government experience agrees, noting that technology has brought "a whole new breed of antitrust problems that lawyers can understand only if they work with technical experts."

Actually, such problems occasionally have surfaced before. The Federal Trade Commission, for example, knew that odometers were built to record more miles than actually were driven—to the benefit of manufacturers and rental firms but to the detriment of owners and renters.

But the FTC failed to act for almost three decades. A group of law students guided by Nader said in a recent report that this was due to the FTC's being "duped by an excuse perennially put forth by the auto manufacturers: they claimed they had to make odometers register high because state highway officials demanded that they make *speedometers* register high (to diminish actual driving speeds) and that the two were inseparably connected . . . the fact of the matter is that odometer and speedometer are not connected, as any mechanical engineer would have known."

While behind-the-scenes maneuvering by the defendants has been intensive, the manufacturers have brought only one public statement on the suit. Although I would question many of the suppositions made in that statement—by AMA president, Thomas C. Mann—I would like to reprint his remarks in the Record an an indication of the type approach the manufacturers are using:

AMA NEWS RELEASE

WASHINGTON, D.C., January 10.—Thomas C. Mann, President of the Automobile Manufacturers Association, today issued the following statement on the suit filed by the Department of Justice against AMA and some of its member companies in Los Angeles:

"We greatly regret the Department of Justice's sudden decision to attack the industry's 15 year old cooperative program to develop and perfect motor vehicle emissions controls. The Department's action is based on a profound misunderstanding of the cooperative program and its actual effects.

"Under this program, initiated at the request of the California authorities, the industry has been developing new technologies for solving this pressing problem of our urbanized society. The program has not hindered or delayed the development and installation of motor vehicle air pollution control equipment. On the contrary, it has already succeeded in reducing the level of hydrocarbon emissions of new cars approximately 63% below the level of the pre-control models, and additional controls now under development are expected to further reduce hydrocarbon emissions to 79% below pre-control models. Moreover, the systems developed as a result of the program have reduced carbon monoxide emissions by about 60%.

"This progress has been made during a period when state and federal regulation has continually taxed the ability of engineers to meet the stringent standards that have been set. It would not have been possible to meet the timetables set by governmental agencies without the cross-fertilization of ideas and the full exchange of technical information among automobile manufacturers and suppliers. This exchange has been made feasible by a royalty-free patent cross-license agreement which all domestic manufacturers of passenger cars, a number of truck manufacturers and many foreign vehicle manufacturers have joined. Although this type of agreement has been praised as encouraging competition, the Department now attacks it.

"With continuing increases in the vehicle population and in the volume of pollutants entering the atmosphere from non-vehicular sources, there is need for even greater reductions in automotive emissions. The manufacturers are now faced with a new requirement for controlling the emission of oxides of nitrogen, a task which in many respects will be more difficult than controlling hydrocarbon emissions. In our judgment, the Department's action today will substantially retard the rate of progress toward all of these goals by casting a serious cloud on the present arrangements and thus reducing the essential flow of information among the participating companies.

"This will be especially harmful to the smaller passenger car and truck companies and to many foreign manufacturers who account for a substantial share of the U.S. market. If these companies are unable to make the necessary progress to meet the more stringent requirements that the regulatory authorities have set for accomplishment within the next several years, the Government will be faced with the necessity of postponing more stringent requirements. If such postponement should occur, the public will be the loser.

"The problem of how Government can most effectively command scientists and engineers to make a new technological breakthrough of this kind, and the corresponding problem of how the industry can most effectively respond to such a command, are both novel and difficult. However, it is difficult to see how any result other than delay and increased cost can come from the Department's action seeking to prohibit the free interchange of technical information about automotive emissions among the firms which are in the best position to find the needed solutions.

"A year ago the President called on Government and industry to join as partners in attacking the problems of air pollution. The automotive industry has done its best to respond to that request. Today's action can only complicate the difficult task of making the partnership a fruitful one."

What Mann said in his statement has more recently been echoed by Chrysler Corp.'s chief engineer, Charles M. Heinen, who told a meeting of the New York

Society of Automotive Engineers that "the main battle against automobile pollution has been won." Dan Fisher of the Los Angeles Times reported on that speech:

EMISSION CONTROL ENGINEER SAYS SO: HAS AUTO SMOG BATTLE ALREADY BEEN WON?

(By Dan Fisher)

"Ladies and gentlemen, let me come to the point: The main battle against automotive air pollution has been won."

That's how Charles M. Heinen, Chrysler Corp.'s chief engineer, emission control and chemical development, opened a speech Wednesday to a meeting of the New York Society of Automotive Engineers.

Heinen, who tends not to mince words, stated: "We have done the job proposed . . . For the sake of perspective, let me say that if there were no other vehicles on the road except the 1969–1970 models, we would—overnight—breathe the same clean air we had in 1940 as far as the automobile contribution is concerned."

To reduce emissions from the levels that will be achieved in the 1970 models "is going to be rough, and it looks like it will be very expensive—in the billions of dollars—to car owners. The next step also raises serious and sincere questions among thoughtful and knowledgeable observers as to how much a further reduction is really necessary and is it worth it from a social, scientific, medical, and economic standpoint."

Heinen suggested that future California and federal regulations—for 1971 models and beyond—will make little significant contribution over what's already been done, and that for that small significant gain, the cost would be $10 billion plus on a national level.

That works out to about $100 added to the price of each car sold in a year.

While hydrocarbons and carbon monoxide are controlled under present California standards, a third pollutant is covered in 1971 California standards—oxides of nitrogen.

Research indicates, Heinen said, that when hydrocarbons are controlled, the reaction of the reduced hydrocarbons and oxides of nitrogen is insufficient to produce photochemical smog.

Although challenging the reasons for control, he said the technology to control oxides of nitrogen is within reach. "Unfortunately, it would mean penalties in cost, performance, fuel economy, and driveability," the emissions specialist added.

He also took issue with California medical authorities who have predicted dire health results from exposure to automobile-caused air pollution. "As a matter of fact, a further review of the medical position would seem to say that the situation is not critical now, or indeed, even serious in the opinion of pretty near everyone except those in California."

The decision about oxides of nitrogen control "should probably be made on the basis of its effect on visibility and on plant damage," he said.

Other automotive engineers have suggested that the least they seek is more time to work on inexpensive solutions to the oxides of nitrogen problem. While the 1971 California standards covering this pollutant can be met at relatively low cost, they say, those proposed for 1972 and 1974 cannot, with present technology.

One auto company engineering vice president has predicted flatly that those standards may be the ones that finally result in a court fight.

Maybe one reason Heinen can call the battle over is that the solutions are not as difficult as the manufacturers would want us to believe. For example, I find this following article from the Los Angeles Times quite fascinating:

REDUCING CAR SMOG EASY, ENGINEER SAYS—SIMPLE ADJUSTMENT CUTS EMISSIONS, HEARING TOLD

(By George Getze)

A simple mechanical adjustment of present-day automobile engines will reduce nitrogen oxide emissions by about 40%, it was stated Wednesday at a public hearing in the New Federal Building.

Robert W. McJones, consulting automotive engineer for the Pacific Lighting Corp., said the reduction would be enough in most cases to bring the cars into compliance with the nitrogen oxides standards already set by California for 1971 model cars.

That is a standard the automobile industry doubts it can meet.

McJones testified that the reduction of pollutants, hydrocarbons and carbon monoxide as well as nitrogen oxides, would be even greater than 40%, if natural gas instead of gasoline were used as fuel.

McJones and Reine J. Corbeil, project engineer for Pacific Lighting, were witnesses Wednesday at a Department of Health, Education and Welfare hearing.

The hearing is being held to collect information that will help Robert J. Finch, secretary of HEW, decide whether or not California is to be permitted to have auto smog standards more stringent than those set nationally by the federal agency.

Most of Wednesday's session was taken up by cautiously worded doubts of the technological feasibility of controlling both nitrogen oxide and hydrocarbon emissions from automobiles, at least in time to meet California's present and proposed standards.

The doubting was mostly on the part of representatives of the manufacturers.

Witnesses from California universities, air pollution agencies and citizens' groups all insisted the standards could be met if Detroit really tried.

"If the automobile makers can't meet the standards with gasoline-fueled vehicles, California should insist upon conversion to gaseous fuels," Corbeil said.

A 40-Percent Reduction

The simple adjustment—which McJones said would reduce nitrogen oxides emissions 40% even on gasoline automobiles—consists of disconnecting the hose or metal line that connects the carburetor and distributor.

The purpose of the hose is to advance the spark timing when an automobile is cruising along, neither slowing down nor speeding up.

The theory is that this saves gasoline, but some automotive engineers doubt that it does.

"When the hose is disconnected the auto operation at full throttle is unchanged, and the ordinary full throttle timing applies at cruising, too," McJones told the HEW committee headed by William Megonnell, assistant air pollution commissioner for HEW.

Corbell said Pacific Lighting had tried the adjustment on 10 Fords, Plymouths, Dodges, Chevrolets and Ramblers, all late models.

He told the HEW committee that only two of the cars met the 1971 nitrogen oxide standards even approximately. When the hose was disconnected, however, all but four met the 1971 standards, even though they were operating on ordinary fuel.

McJones and Corbell said there was no adverse effect on performance.

Typical reductions, for example, were from 2,500 parts of nitrogen oxides per million parts of air, to 1,000; 1,300 ppm to 800, and 3,400 ppm to 1,400.

Expresses Doubt

The chief witness for the automobile industry was Donald Jensen, who used to be executive head of the California Motor Vehicle Pollution Control Board but who now works for the Ford Motor Co. He also spoke Wednesday for the Automobile Manufacturers' Assn.

"There is a substantial question whether the California oxides of nitrogen standards can, in fact, be met by all vehicle manufacturers," Jensen told the committee.

He said the association "neither supports nor opposes California's request" for standards more stringent than the national ones.

When Jensen finished his prepared statement Megonnell pointed out that he had heard very little in it of support for California's request but a lot of opposition.

Another member of the HEW committee, Kenneth Mills, asked Jensen if Detroit would make any progress at all in controlling pollutants such as oxides of nitrogen, if very stringent standards were not adopted.

Jensen answered that the industry would make progress and would work at controlling the pollutants, even if it was not required to do so by strict standards.

Calls for Faith

"What the chairmen of the boards of the automobile corporations say can't be taken lightly," Jensen told the HEW committee.

He said it must be taken "on faith" that these board chairmen really mean what they say, and they say auto makers are going all out to control air pollution from automobiles.

The Department of Justice replied Wednesday to Dep. Atty. Gen. Charles O'Brien's charge, made the day before, that it had used fraud and chicanery in trying to block California's investigation of auto smog.

O'Brien used the hard words in telling the HEW committee that federal attorneys had blocked his efforts to get information from Wallace Linville. Linville, a smog expert, had testified before the U.S. grand jury investigating Detroit's efforts (and alleged lack of efforts) to control auto smog emissions.

A spokesman for the Department of Justice said Wednesday that a federal law prohibits persons from disclosing testimony before a grand jury, which was why Linville was advised not to answer all of O'Brien's questions.

He denied any fraud or chicanery was involved.

"The department has cooperated and will continue to cooperate with the state's endeavor to investigate the automobile manufacturers' air pollution control record," the spokesman said.

As Heinen points out, current controls, devices and regulations for new motor vehicles have gone far in easing the seemingly exponential growth of air pollutants, but the emissions from the millions of older cars not subject to the stringent laws continue pouring ton after ton of smog into the air. If the battle is over, it is going to be one heck of a mopup operation.

Certainly, the advances in cutting down pollution from nonvehicular sources have been impressive. As the following Los Angeles Times story notes, the Los Angeles basin has apparently eliminated all pollution eminating from powerplant smokestacks, and says:

"The automobile is now contributing more than 90% of the total tonnage of pollutants in Los Angeles air."

The article follows:

LOS ANGELES AREA CALLED FREE OF POWERPLANT SMOKE—THOUSANDS OF COMPLAINTS CUT TO ONE BY USE OF LOW-SULFUR FUEL OIL, FULLER DECLARES

(By George Getze)

Smoke and chemical fallout from electric power plant smokestacks have disappeared "almost miraculously" in the Los Angeles Basin, Louis J. Fuller, head of the Air Pollution Control District, said Tuesday.

Instead of the usual thousands of complaints of smoke plumes and fallout that have poured in on the APCD, there was only one complaint last winter and spring, Fuller said.

He said the drastic change was due to the burning of low-sulfur fuel oil when not enough natural gas was available in cold weather.

Fuller said the APCD now forbids the burning of any fuel oil when natural gas is available. But until federal regulations were changed to permit the importation of low-sulfur oil from Indonesia, cold weather meant that high-sulfur domestic oil was burned.

The federal permission to bring low-sulfur oil into the United States is good only through next winter. Fuller said the APCD has already begun to fight for permanent permission.

"In view of the tremendous improvement in plumes and fallout, it is unthinkable that permission to bring in low-sulfur oil should not be continued," Fuller said.

DENIES RELAXING FIGHT

The APCD chief's remarks were made in an interview in which he replied to charges that the APCD had relaxed its fight against stationary sources of smog in the Los Angeles basin.

The accusation has been made twice recently, once last month before the Board of Supervisors and once last week before the State Air Resources Board, by a group of women called Stamp Out Smog.

They said that smokestacks were "mushrooming," that the county's air pollution control is no longer the model for the rest of the world, that it is going backward instead of forward, that variances to APCD rules are granted wholesale and that smog control officers have lost the energy and initiative they had 10 years ago by not following through on a suggested rule that would have prevented the construction of more power plants in Los Angeles County.

Fuller said it's nonesense.

Smokestacks, thanks to the APCD's fight to provide low-sulfur fuel, don't smoke in Los Angeles County, so that any remark about their "mushrooming" is meaningless, he said.

"Our control of stationary sources is more of a model for the rest of the world now than it ever was," Fuller said.

Another example he cited was the federal government's publication of a field operations manual describing APCD enforcement practices as models for other agencies throughout the world.

So far, APCD is the only district in the world to have begun the regulation of such inconspicuous sources of air pollution as the evaporation of volatile organic solvents used in paints, inks and dry-cleaning compounds, he said.

APCD was also responsible for the drafting of new state law regulating the emission of black smoke from jet airplanes, Fuller said. It will go into effect Jan. 1, 1971, in order to give the airlines time to comply.

SAYS VARIANCE MISUNDERSTOOD

Fuller said the matter of variances to these rules is misunderstood. The APCD grants no variances. They are all granted by the Air Pollution Hearings Board, created by the State Legislature.

He said air pollution experts realize it is often impossible for companies to comply immediately with new rules, and that they must have time to get new equipment or modify what they have.

Many of the current variances, for example, have been granted to give firms time to comply with Rule 66, the one governing the evaporation of organic solvents. Fuller said any fair examination of the variances that have been granted would show no maladministration by the hearing board, but instead a very careful regard for the public welfare.

He said the evaluation of emissions from automobiles and stationary sources shows that the control of stationary sources is excellent, and that the automobile is now contributing more than 90% of the total tonnage of pollutants in Los Angeles air.

"The remaining problem in Los Angeles is almost entirely with the automobile, although that can't be said for some other counties in the Bay Area and farther north," he said.

Latest statistics show that 9,695 tons of carbon monoxide are emitted here by automobiles every day, compared with 35 tons by stationary sources. The figures for hydrocarbons are 1,820 tons from the automobile, and 730 tons from stationary sources.

Fuller agrees with A. J. Haagen-Smit, chairman of the Air Resources Board, that one of the biggest problems is the control of nitrogen oxides, which are the product of all kinds of burning.

Nitrogen oxides are an important emission of stationary sources such as power plant smokestacks, but figures submitted by the Air Resources Board last week show that even with them industrial burning is a less important source than automobiles.

The ARB report shows that daily emissions of nitrogen oxides in Los Angeles are 939 tons, of which 575 come from auto exhausts and 258 from industrial burning of fuel. Other sources are minor.

To control the nitrogen oxide emissions from power plants, Fuller a year ago suggested a new APCD rule, No. 67.

In a letter to the supervisors, he said the rule would prevent construction and operation of new "monster" power plants or any other fuel-burning installation unless they were equipped with very efficient pollutant controls.

The suggested rule would have forbidden the operation of any equipment unless discharges into the atmosphere were limited to 200 pounds an hour of sulfur compounds, 140 pounds an hour of nitrogen oxides and 10 pounds an hour of dust or "particulate matter."

Stamp Out Smog has accused the APCD of losing initiative and energy because it has not followed up this suggestion by pressing the supervisors.

Fuller said Tuesday that he had decided after conferring with the Department of Water and Power, that the rule is not necessary now.

He said the department was adding one boiler to the Scattergood plant at Playa del Rey, and that though it would contribute oxides of nitrogen, it would permit the phasing out of older boilers that contribute more.

In any case, no move is under way to build any of the "monster" power plants he had in mind when he wrote to the supervisors.

"If Rule 67 should become necessary I won't hesitate to submit it to the supervisors," Fuller said. "I am waiting now to see whether or not it will be needed. If it is, it is all ready."

To show an overall perspective of the Air pollution problem—with special emphasis on the particular situation in Los Angeles—I would like to insert the following series of articles from the Los Angeles Times. Taken as a whole, the picture thus presented in them does not seem overly optimistic, and, indeed, the outlook I get is not extremely promising—given the laggard rate at which society seems to be energizing its resources in this critical struggle just to maintain the current quality of our air.

The articles follow:

No More Alerts or Eye Irritation, Experts Say: 1970's Expected To Bring Victory Over Smog

(By George Getze)

The 1970s will be the decade of realization in Los Angeles County's long fight against air pollution.

By 1980 most cars and trucks on the road will be equipped with control systems that meet the standards set by the California Pure Air Act.

It will take that long because of the time lag in used cars, but, according to the Air Pollution Control District, by the end of the '70s the air of the Los Angeles basin will have 83% less hydrocarbons than it has now. There will be no more smog alerts they say, and eye irritation will be rare.

Visibility obviously will be better although the brown haze of nitrogen dioxide still will be seen occasionally. Oxides of nitrogen in the atmosphere will have decreased 41%.

The APCD says these results will depend on state and federal insistence that automobile makers manufacture cars and trucks with exhaust control systems efficient enough to meet the strict California standards that will all be in effect by 1974.

The accompanying graph shows the status of automobile air pollution as the 1970 decade begins.

The number of cars in the county is increasing and will continue to increase. This increase amounts to 31% in the nine years since 1960.

Despite that, the exhaust and other controls already in effect have resulted in decreases in two of the chief pollutants of Los Angeles basin air—hydrocarbons and carbon monoxide, both of which have been declining since 1965.

Decrease of 16 Percent

The decrease in hydrocarbons since the peak amounts to 16%. (To appreciate what has been accomplished one must consider what might have been if control had not been begun. If the emissions of hydrocarbons had risen in the same proportion as the number of automobiles, the daily tonnage of hydrocarbons in the atmospehere would now be 2,500 instead of 1,645.)

The decrease in carbon monoxide amounts to 12%. (It would be 11,380 tons a day instead of 9,100 if the present controls had not been applied.)

But as has been pointed out many times, the act of controlling hydrocarbons and carbon monoxide has improved combustion, and this has tended to make automobile emissions of nitrogen oxides worse.

This improved combustion with the increasing number of cars, accounts for nitrogen oxide emissions rising by 66% since 1960.

Controls are about to be applied to them, too, even though the automobile industry is protesting that it can't do the job on schedule. The state's answer is that it will have to if it wants to sell cars in California.

Here are the auto emission standards that will be in effect for all 1974 model cars sold in California:

Hydrocarbons—1.5 grams per mile, of 125 parts per million, beginning in 1972. (The standard for 1970 model cars is 2.2 grams per mile, or 180 ppm.)

Carbon monoxide—23 grams per mile, or about 1% by volume of exhaust gas, beginning with 1970 models.

Nitrogen oxides—1.3 grams per mile, or about 350 ppm, beginning with 1974 models. (There will be no standard for 1970 models, but 1971 models will have a standard of 4 grams of nitrogen oxides per mile, or about 1000 ppm, and 1972

and 1973 models must emit no more than 3 grams per mile, or 800 ppm of nitrogen oxides.)

Clean air in Los Angeles, even with control of automobiles as projected in the Pure Air Act and enforced by the Air Resources Board, would not be possible without control of stationary sources.

Cars Worst Offender

By far the greater part of Los Angeles County air pollution comes from the automobile, but that is only because the APCD has been applying controls to stationary sources for more than 20 years.

The measure of success is evident in the fact that 88% of Los Angeles pollutants comes from cars.

Ninety-eight per cent of carbon monoxide, 68% of nitrogen oxides, 68% of hydrocarbons and 41% of dust (particulate matter) comes from automobile exhausts, crankcases and evaporation from gas tanks.

That is why control of the automobile emissions in the 1970s plus continued improvement of the control of remaining stationary sources, should bring blue skies and clean air back to Los Angeles basin.

But There Will Still Be Smog

(By Irving S. Bengelsdorf, Ph. D.)

A razor blade company once ran a humorous ad showing a young man, his face lathered, falling off a skyscraper. As he fell, he was shaving himself and saying. "By using Company X's razor blade I save 11.4 seconds each morning when I shave."

This certainly was an interesting shortrange statistic, but as far as his long-range future was concerned—as he plunged earthward to imminent doom—it was most irrelevant.

The same is true of the long-range future of smog in southern California. Although our air now is so filthy that for more than half the year it exceeds the air quality standards for certain pollutants set by the State Department of Health, we are told that by having this or that emission control on automobiles of smokestacks, we now prevent many tons of pollutants from getting into the air. Irrelevant. We still have smog.

We once were told by the now defunct Motor Vehicle Pollution Control Board that we would "Return to the Clean Air of 1940." One need not be very clairvoyant to look at Los Angeles in 1969 and realize that very little—surely not the air—is going to return to the way it was in 1940.

Now we are told that by the 1980s blue skies and clean air will come back to the Los Angeles basin. The new stricter standards for automobile emissions—to be in effect by 1974—will do the job. This is based upon the assumptions that cars coming from Detroit after 1973 will meet the stricter California emission standards, and that they will continue to do so as they age and are driven thousands of miles. We have no guarantee that either assumption is valid.

But, let us suppose that cars after 1973 do, indeed, meet the stricter emission standards. In 1980, it is estimated, there will be at least about 5.2 million cars in Los Angeles county. About half of these 5.2 million cars will be tossing out 1.3 grams of nitrogen oxides per mile—the strict California emission standard beginning in 1974. The other half—those cars built before 1974—will be putting out three, four, or more grams per mile.

But, let us assume that *all* 5.2 million cars in 1980 put out only 1.3 grams of nitrogen oxides per mile. Each car, on the average, will burn about two gallons of gasoline per day. Assuming an average mileage of 15 miles per gallon, each car should travel about 30 miles par day.

Thus, 5.2 million cars travelling 30 miles per day, putting out 1.3 grams per mile, would toss out about 203 million grams of nitrogen oxides per day. With 454 grams in a pound, and 2,000 pounds per ton, the 5.2 million cars would spew out about 225 tons of nitrogen oxides per day.

How much of each pollutant has to be present in Los Angeles air to make smog appear? Some calculations indicate that smog can be present in the basin if there are between 200 and 250 tons of nitrogen oxides per day. Since automobiles will account for most of this by themselves in 1980, there isn't much room left in the air to accommodate the nitrogen oxides pouring out of smoke-

stacks of power plants generating electricity. And the demand for electricity in this area has been doubling almost every nine years.

For the long-range future of the southern California air resource, the willy-nilly patchwork approach of an emission control device here, and another there, will not work.

Five years ago, in a statewide conference entitled "Man in California—1980s," Dr. Philip A. Leighton, emeritus professor of chemistry at Stanford, warned, "Air pollution may be likened to a weed. Controls may clip back the weed but they will not keep it from growing up again. To kill the weed we must get at the root, and the root of the whole problem of general air pollution is combustion (burning)."

It should be obvious that if we are to attain a population of 18 million people in the Los Angeles *megalopolis by the year 2000, as predicted by some, we must* begin now to change drastically both our ways of personal transportation and the generation of electrical energy.

Experts Solve Smog Puzzle, Create Another

(By George Getze)

Engineers and scientists have to face up to a very basic chemical fact in going about the job of trying to control Los Angeles smog.

It is this: One of the chief ingredients of photochemical smog, the hydrocarbons or organic gases, is the result of inefficient and incomplete combustion, but the other two, sunlight and the oxides of nitrogen, are not.

The oxides of nitrogen, in fact, are the natural result of combustion and the more efficient that combustion is the more oxides of nitrogen are produced.

When California authorities forced automobile makers to begin controlling hydrocarbon and carbon monoxide emissions they went about it by increasing the efficiency of gasoline combustion.

This was accomplished by adjusting the carburetor to a "leaner" mixture of air and gasoline—that is, more air and less gas.

Oxides of Nitrogen Rise

It has worked, and hydrocarbons and carbon monoxide emissions from automobiles have diminished.

Another, not so pleasant, effect of more efficient automobile engines has been to increase automobile emissions of oxides of nitrogen.

This is because the atmosphere of the earth is almost entirely nitrogen and oxygen—about 80% and 20%, respectively. The two gases are physically mixed in the atmosphere but not chemically united.

When air is subjected to high temperatures, as it is when it is burned in an engine or furnace, the two gases of the atmosphere combine to form nitric oxide—one atom, of each.

This happens no matter what fuel is burned. Nitric oxide will form if hay or carrots, or any other conceivable fuel, is burned.

(Tobacco, for example, produces nitric oxide when burned. Taking a drag off a cigaret gives the smoker a jolt of 500 parts per million—about the same that he would get if he stuck his head in a power plant smokestack and took a deep breath.)

The more air exposed to the heat and pressure, the more atoms of oxygen and nitrogen combine.

Sixty-Eight Percent Due to Autos

That is the most important reason the burning of gasoline in a "leaner mixture" has resulted in an increase of nitrogen in Los Angeles air.

Another reason is that automobiles produce about 68% of these oxides emitted daily in the basin. Electric power generating plants are the next biggest contributor, with 185 tons daily or 14%, compared to 645 from motor vehicles, followed by relatively minor sources—the oil refineries (40 tons daily or 4%) and the heating of homes and offices (65 tons daily in cold weather or 6.5%).

Unfortunately, the process of smog formation is not complete with the emission of nitric oxide.

Nitric oxide, when it gets into the air from an auto exhaust or power plant smokestack, reacts chemically by picking up another atom of oxygen to form nitrogen dioxide.

This is the pollutant that is one of the essential components of photochemical smog. *It also is the one that causes the ugly brown haze.*

In the absence of light, this chemical reaction is a slow one. When it takes place in bright sunlight, especially in the presence of the organic gases, or hydrocarbons, the reaction is rapid and thorough.

Controlling the oxides of nitrogen, it is clear, is not a matter of improving efficiency of combustion. It is a problem of an entirely different kind.

As long as there is any burning at all, oxides of nitrogen are bound to be present in the air.

All that it will be possible to do, short of doing away with Los Angeles altogether, is to ameliorate conditions.

The Air Pollution Control District, however, expects this amelioration to be substantial.

The APCD estimates that by making certain changes in the automobile engine and by strict enforcement of emission standards already set, the oxides of nitrogen in the basin's atmosphere can be reduced 41% by 1980.

That will not be perfect. Alerts probably will be a thing of the past, but Los Angeles still will occasionally have brown haze and eye irritation even then.

Still, it will be quite an amelioration.

Two methods have been suggested for reducing the oxides of nitrogen emitted from auto exhausts.

Robert McJones, a consulting automotive engineer for the Pacific Lighting Corp., recently testified at a federal public hearing that retarding the spark would cut nitric oxide emissions 40%.

Retarding the spark reduces the peak temperatures in the cylinders and, consequently, less nitric oxide is formed.

Although representation of the automobile industry who attended the hearing acted as though they had never heard of such a thing, retarding the spark is now considered the most likely step the industry will take to meet the California emission standards for 1971 model cars.

The 1971 limit for cars sold in California will be 1,000 parts of nitric oxide per million parts of exhaust gases.

To meet the much stricter 1972 and 1974 standards (800 ppm and 350 ppm) something else will have to be done.

One way that has been suggested is to lower the temperature of combustion by recirculating 15% or so of the exhaust gas so that it goes through the engine a second time, after the oxygen in it has been used up.

The inert, recirculated exhaust gas sops up some of the heat in the cylinder—and thus also effectively the nitric oxide.

THE PRICE OF CLEAN AIR

"The main battle against smog has been won."—Charles M. Heinen, chief engineer, emission control and chemical development, Chrysler Corp., April 9.

"The peak output of automobile-produced smog in Southern California definitely has passed—and will never be as high again."—Dr. Fred Bowditch, director of emission control, General Motors, Aug. 5.

"The third consecutive smog alert was called Friday in the Los Angeles Basin as a blazing sun continued to cook pollutants in the air."—The Times, Aug. 23.

There is a kind of grim irony in the recent public concern over the potential threat from transportation and storage of military poison gases.

City dwellers throughout the nation already are slowly poisoning themselves by inhaling the air polluted by automobiles. The threat is actual and still unabated.

Nowhere is the peril of auto-caused air pollution more serious than in the Los Angeles Basin.

At least 10,000 persons leave each year on the advice of their physicians. The millions that remain simply suffer and complain that "something must be done."

Something has been done. But not enough and not quickly enough.

Although emission control regulations have brought about a reduction in the total amount of hydrocarbons and carbon monoxide, experts say the skies over Los Angeles will not be substantially cleared of pollutants until 1980.

That timetable, however, could be accelerated—if smog sufferers would pay the price.

Air pollution control can be as strict as the people want it to be. California demonstrated that public pressure is stronger than all the auto industry lobbyists when it forced Detroit to install smog control devices.

Congress also was responsive to the collective outrage of Southern Californians who demanded that this state be allowed to set tougher emission standards than the federal requirements.

Although Detroit complains, it will comply with the increasingly stringent regulations set by the Legislature for new cars in the 1970 model year and subsequently. No industry wants to give up its biggest market.

But even with improved devices, the fight against smog moves slowly because a majority of the cars in the Los Angeles Basin still have no exhaust control system at all. The total of motor vehicles in the basin, moreover, increases by nearly 10% every year.

To achieve a substantial improvement in air quality, therefore, every one of the more than 4 million cars and trucks in Los Angeles County must be equipped with an emission control device in proper working order.

This would mean that every owner of a pre-1966 vehicle would have to assume not only the initial cost of such a device but also the expense of maintenance and at least annual inspection. In Los Angeles County alone, the total price would amount to hundreds of millions of dollars.

The Legislature mandated installation of control equipment on used cars but only if two acceptable devices were available and if their cost did not exceed $85. Neither condition has been met.

Much more must be done to develop feasible inspection of the control systems installed at the factory. Unlike the crankcase blowby, these devices cannot be properly inspected with a quick look under the hood.

So long as the public insists on buying big cars with excessive horsepower, the fumes they produce can be reduced only by better control equipment subject to periodic maintenance and inspection—until there is a major breakthrough in engines or fuel.

Detroit says that turbine or steam engines or one powered with natural gas are not yet practical and may never be. Oil companies similarly offer little encouragement that pollution can be reduced by modifying present fuels.

Perhaps. But if the public outcry were loud enough, more action would be motivated in industry—and in government. Why is not the federal government doing more independent research in these two areas?

The ultimate cure was proposed by State Sen. Nicholas Petris (D-Alameda) when he proposed that the internal combustion engine be outlawed in California in 1975.

Not long ago, his bill would have drawn nothing but laughter from his colleagues. This year it passed the Senate and had support in the Assembly before being defeated.

Life without one—or two or three—cars seems unthinkable to most Southern Californians. But life may be unbearable if auto-caused air pollutants are not drastically curtailed, and before 1980.

The air can be made cleaner, just as other kinds of environmental pollution can be controlled. But smog will not diminish until the public demands—and supports—corrective action.

EXPERT SAYS CITIES DON'T HAVE CHOICE BETWEEN CLEAN, DIRTY AIR—CANADIAN ECONOMIST TELLS SCIENCE MEETING URBAN AREAS MUST DECIDE WHAT DEGREE OF CONTAMINATION IS ACCEPTABLE

(By George Getze)

Los Angeles and other modern cities do not have the choice of clean air or dirty air.

The realistic question they must answer, according to a Canadian economist, is what degree of contamination will be found acceptable.

R. M. Clinkscale said Monday at the Anaheim Convention Center that the quality of air available to every city will be a compromise in pollution.

"The only total answer to air pollution is to put an end to all combustion," Clinkscale said in an interview.

"Nobody wants to take that drastic a cure, and nobody who realizes what would be to put an end to all combustion," Clinkscale said.

He was a speaker Monday at the 15th annual technical meeting of the Institute of Environmental Sciences. Theme of the 1969 meeting is man in his environment.

"There is a basic conflict between those who want to use the air for basic life support, and those who want to use it for waste disposal," Clinkscale said.

He does not think the polluters should necessarily have to pay the whole bill for cleaning up the air as much as is possible.

"There is no market mechanism to resolve that conflict," he said. "That is, there is no economic method that would solve the problem of pollution through the ordinary workings of profit and loss.

"You can't buy and sell clean air, and there is no profit incentive for a firm to pay for waste disposal when it doesn't have to," he said.

In Southern California, Clinkscale pointed out: the polluters and the people who want the air chiefly to breathe are the same people—the automobile drivers.

Clinkscale does not think many local communities have really thought this out, especially how much it will cost.

Los Angeles, he said, has done far more than any other city in the world, but even in California it has not been entirely decided how cleaning up the air will be paid for.

For instance, Clinkscale said, strict control of automobile emissions will not be enough. There will have to be periodic inspections of the control devices and systems to be sure they are working properly. Such inspections will be expensive.

"Every community or air basin will have to decide what level of air quality it will enjoy—and how that quality will be paid for," Clinkscale said.

"It's the paying for it that will determine the quality."

Threat to Survival, Scientist Warns: Air Pollution Peril: Ice Age or Hot House

(By George Getze)

Continuing air pollution will bring about one of two conditions—both highly unpleasant and both dangerous to man's survival on earth, according to Dr. A. J. Haagen-Smit, chairman of the Air Resources Board.

Dr. Haagen-Smit said Wednesday that one result of air pollution may be to produce the famous "greenhouse effect" that would heat up the earth's atmosphere and make earth more like Venus is thought to be.

The other possibility is for the increasing amount of pollution particles in the atmosphere to act like a screen to keep out the sun's rays, resulting in a drastic lowering of the temperature and a new period of glaciers.

Scientists are worried about both possibilities, with some—considering the cooling off more likely and others the heating up.

"We don't know yet which school is right."

Dr. Haagen-Smit said.

"But we'd better do something before we've either melted the polar ice caps and flooded the world's biggest cities, or before we have to suffer through an era of glaciation."

Dr. Haagen-Smit is professor of bio-organic chemistry at Caltech and the scientist responsible for fixing the blame of Los Angeles smog on the automobile.

It was he who discovered the chemical make-up of photochemical smog; that is, smog that is the result of the effect of light on organic pollutants in the atmosphere.

He said this generation is seeing important man-made changes in the atmosphere of earth.

"In burning the fossil fuels of coal, oil, and gas, we are increasing the carbon dioxide in the air by about .03 percent every year. This concerns many scientists who predict a rise in temperature because of the insulating effect of carbon dioxide."

Dr. Haagen-Smit said other experts point out that the increase of the load of particles carried in the atmosphere (that is, its general dirtiness) could lead to a decrease in temperature because of increasing reflection of the sun's rays by this layer of particles.

"Our ancestors lived in the happy certainty that the earth was infinite, that there was enough soil, water and air to go around forever," he said.

"But now, looking at the earth from an astronaut's vantage point, we have begun to realize that the earth isn't so big, and that the apparent stability applies only to our own time, an infinitely small thing in the time scale of geologic changes," Dr. Haagen-Smit said.

Dr. Haagen-Smit spoke at the international symposium on man and beasts sponsored by the Smithsonian Institution in Washington, D.C.

Smog Periling Desert as Health Site, State Told—Riverside County Official Seeks To Halt Flow of Pollution Through Pass

(By George Getze)

Air pollution upwind from the Cochella Valley may mean the "twilight of the desert" as a health and recreational area, a Palm Springs man Tuesday told the State Air Resources Board.

Fred Metheny, representing the Regional Anti-Pollution Authority of Riverside County, asked the ARB for "protection from the smog invasion from the west."

San Gorgonio Pass, Metheny, said, is like a shotgun aimed at the hearts of Palm Springs, Palm Desert, Indian Wells, Desert Hot Springs, Indio and other towns in the desert.

The lethal ammunition is smog from Riverside, Fontana, Los Angeles and other areas west of the low desert valleys, Metheny said.

Metheny was a witness before the ARB in the first of a series of public hearings to discuss air quality standards for the whole state. Other hearings will be held in San Francisco, Sacramento, San Luis Obispo and Eureka.

Opposed to Construction

Metheny said the desert communities which banded together in the anti-air pollution authority are opposed to the construction of power stations, refineries and other industry in the Beaumont-Banning area in San Gorgonio Pass.

He asked Dr. A. J. Haagen-Smit, chairman of the ARB, for advice on how to prevent their construction.

Dr. Haagen-Smit said he had asked the attorney general's office what could legally be done by one community to control air pollution in a neighboring community.

His advice to Metheny and the desert communities was to make their own air quality standards as strict as possible, and then try to persuade the Riverside County Board of Supervisors to refuse permits for industrial construction in the pass.

If that doesn't work, the question will have to be worked out in the courts. Dr. Haagen-Smit advised.

He said enforcement of air quality standards throughout the state will alleviate the problem faced by the resort communities that are subjected to the air pollution of industrial neighbors upwind.

The ARB, Dr. Haagen-Smit said, is considering setting air quality standards for six pollutants. They are oxidants (including ozone), carbon monoxide and nitrogen dioxide, all important elements of automobile smog like that in Los Angeles, and sulfur dioxide, hydrogen sulfide and man-made dust, which the Air Pollution Control District has largely controlled in Los Angeles but which are serious nuisances elsewhere.

Work Out Standards

The standards being considered were worked out by the State Health Department and the ARB's technical advisory committee, and are as follows:

Oxidants (including ozone), a density of .10 parts per million lasting an hour.

Carbon monoxide, .20 ppm for 8 hours.

Sulfur dioxide, .10 ppm for 24 hours, or .50 ppm for 1 hour.

Particulate matter, or dust, enough to reduce visibility to 7½ miles on the smoggiest days.

Hydrogen sulfide, .08 ppm for 1 hour.

Nitrogen dioxide, .25 ppm for 1 hour.

Dr. Haagen-Smit explained that when these standards have been adopted it will be the duty of the ARB to see to it that local and state authorities enforce them.

Local communities, such as Palm Springs, may have standards stricter than those adopted by the state.

The oxidant, or ozone, level is the one used to determine the degree of smog in Los Angeles and the one on which smog alerts and the new special school warnings to reduce exercise are based.

In a special report presented by the ARB Tuesday, downtown Los Angeles was shown to have had 176 days in 1967 in which the proposed oxidant level was exceeded. (That year is the most recent for which statistics have been completed.)

Azusa had 225 such days that year, Pasadena had 218; Burbank, 204; Pomona, 207; Anaheim, 152; Santa Ana, 69.

Salinas, in Monterey County, had 3; San Rafael, in Marin, had 17; San Francisco had 12; San Jose, 81; San Diego, 35; Sacramento, 49; San Bernardino, 173; Cucamonga, 217; Fresno, 86, and Oakland, 20.

Another table in the same report compared 1967 oxides of nitrogen emissions in four metropolitan areas.

Los Angeles-Orange County's daily emissions averaged 939 tons, of which 575 tons of oxides of nitrogen came from automobile exhausts; 40 tons from oil refineries, and 258 from industrial burning of fuel. Other sources were minor.

San Francisco-Oakland's daily emissions averaged 500 tons, of which 273 came from auto exhausts, 186 from industrial fuels and only 9 tons from oil producers.

San Diego's average daily tonnage of oxides of nitrogen was 173, 92 tons of which was from automobiles and 65 tons from industrial fuels.

The August-September issue of the National Wildlife, the excellent publication of the National Wildlife Federation, contains a new feature called the EQ—Environmental quality—index. And, of the six components making up the total index—air, water, soils, minerals, forests, and wildlife—the quality of our Nation's air rates lowest. In making its rating, National Wildlife said this:

Air pollution is probably the most serious threat to our Environment Quality. It is a silent killer which hovers over every city in our nation and touches the creatures of the polar life zones.

So our Air Quality Index stands at very bad. The Trend: We are losing.

It is a frightening kind of pollution that colors our skies, burns our eyes, blackens our lung tissues, darkens our white houses, dissolves nylon stockings, corrodes metal, hardens rubber, and dust-coats everything. I must clean the apples from my trees. Rainwater is no longer good for washing hair, my daughters tell me.

And air pollution is worse than it looks. Particles are the only air pollution you can see; the deadly gasses are invisible. It is suspected that polluted air is a major factor in causing emphysema, bronchitis and lung cancer.

When London was hit by a four-day "killer smog" in December, 1952, the "excess death toll" was estimated at 3,500 to 4,000 persons. In 1948 a stagnant air mass over Donora, Pennsylvania, choked its 15,000 residents, killed 20 and made more than 6,000 sick.

Automobile exhaust is by far the greatest polluter, followed by home heating, industry, and the burning of garbage and other wastes.

Belatedly, some progress is being made to control it. The National Air Pollution Control Administration is attacking the problem on a regional basis, with primary responsibility for clean-up resting with state and local governments. The country is being divided into 57 Urban-Industrial Air Quality Regions and, hopefully, by the summer of 1970 local authorities will have set up air quality standards to be enforced by state and local officials. If they fail, the Federal government may then step in and enforce the standards.

All but four states—South Dakota, Nebraska, Alabama and Maine—have air pollution control laws now.

But that is only the start of the battle. It is amazing how little is known yet about the full effects of air pollution on human health, and how little we are spending to control it.

Air pollution is the more serious kind of pollution since once in the atmosphere man is helpless and must rely on nature to purify it. (And that means washing it down to our land, where it goes into our rivers and on to the sea.) As long as we are so short-sighted as to use the atmosphere as a garbage dump, our air will become dirtier and more dangerous.

The current quality of our air is a national disgrace. And America's automotive syndrome has been the major contributing factor to the steady decline of that quality. For years, Government attempted to use the carrot approach to entice auto manufacturers to do something about the problem, and for years, the manufacturers procrastinated as they claimed that they were indeed doing all they could do.

As I quoted in my letter to Attorney General Mitchell, Los Angeles County Supervisor Kenneth Hahn started writing the manufacturers back in the early 1950's, asking them what they were doing to ease the mounting smog. Each

year or so, Hahn would write, and each time, he would receive back equally evasive answers. Finally, as Supervisor Hahn wrote in a letter to President Johnson:

I have found out that you cannot "cooperate" or urge them "voluntarily" to do the job.

And so, if the carrot does not work, it is time to use the stick. The stick was wielded by the Justice Department in bringing this important suit, and I hope it is used more and more as needed. But, to opt for a consent decree in this case would amount to dropping the stick altogether. Were that done, I am sure the results would be disastrous.

The time is short before the Justice Department makes its choice on the manner of deciding this suit. The need for a public trial is overwhelming. Already 20 or so Members have expressed their views on the necessity for this public hearing, and I would hope that similar sentiments are soon forthcoming from many more of my colleagues as well as from all citizens and organizations who are worried about the quality of our delicate environment.

Ralph Nader Criticizes Consent Decree in Smog Case

(By Hon. George E. Brown, Jr.)

Mr. BROWN of California. Mr. Speaker, last week the Justice Department took a giant backward step in the crucial struggle to maintain the quality of this Nation's atmosphere when it asked for a consent judgment in the antitrust suit brought against automobile manufacturers who were accused of conspiring to retard development of effective smog controls.

My view of the Justice Department action is that the Nixon administration sold out our right to have clean air so that automobile manufacturers can maintain sizable profit margins. Over the past weeks, I have attempted to impress both Attorney General Mitchell and Antitrust Division Chief Richard W. McLaren with the importance of holding an open public trial in this vital case.

Certainly I have not been alone in this effort. Many other concerned Members of the House, along with numerous individuals and organizations, also urged the Justice Department to call for an open trial. In two instances, there were interventions into the case from a large government unit, Los Angeles County, and a private group, ASH, as indications of the importance of the overall issues at stake. But, so far, all have been of no avail.

Under court proceedings employed in antitrust suits, the final decision by the district court will not be made until 30 days after the decree was requested, and during this period, the ledger is open for all concerned parties to attempt and contest awarding of the decree.

Major drives already are underway to try and sway the court and the Justice Department to reverse last Thursday's move, and instead ask for the open trial.

Today, I have received a letter written to Mr. McLaren by Ralph Nader in which Mr. Nader takes a deep and quite critical look at the consent decree itself, and at the larger issues which pervade this case.

I believe this letter serves as a penetrating blow to the Department allegations that the decree contains all that the Government desired in its original complaint.

Therefore, I would like to put into the Record at this point three items: First, the Justice Department press release telling about the consent judgment; second, the consent judgment; and finally, Mr. Nader's letter:

Department of Justice Release, September 11, 1969

The Department of Justice filed today a proposed antitrust consent decree prohibiting the four major auto manufacturers and the Automobile Manufacturers Association from conspiring to delay and obstruct the development and installation of pollution control devices for motor vehicles.

The decree also requires them to make available to any and all applicants royalty-free patent licenses on air pollution control devices and to make available technological information about these devices.

Attorney General John N. Mitchell said the decree, filed with the United States District Court in Los Angeles, would be submitted to the court for final approval in 30 days. Its provisions would become effective immediately thereafter.

The proposed decree, signed by General Motor Corporation, Ford Motor Company, Chrysler Corporation American Motors Corporation, and the Association, would conclude a civil antitrust suit filed by the Department on January 10, 1969.

Mr. Mitchell said that the proposed decree "represents strong federal action to encourage widespread competitive research and marketing of more effective auto anti-pollution devices."

Mr. Mitchell said that a continuation of the suit—which may have taken years in court litigation—would have delayed Justice Department efforts to end the alleged conspiracy and its efforts to encourage immediate action by the automobile companies.

The Attorney General said that the consent decree should spur aggressive competitive research and development efforts by each auto company and by other companies, and therefore should prove to be a substantial benefit to the health and welfare of all metropolitan area residents—especially those in the Los Angeles Basin which has the most serious smog problem in the nation.

The Attorney General also said that the judgment is in line with the massive antismog program announced two weeks ago by Dr. Lee A. DuBridge, President Nixon's science advisor, at a meeting of the President's Environmental Quality Council.

Dr. DuBridge said, "Nowhere is there a greater need for urgency than in the field of air pollution, which affects directly the health and comfort of our people. I think speedy resolution of this case will promote competitive research and development in the design and installation of smog control devices and represents an important step forward in the fight against pollution."

The Department of Health, Education, and Welfare, which administers the Clean Air Act, and the representatives of the Air Resources Board of the State of California, have expressed satisfaction with the terms of the proposed consent decree.

Assistant Attorney General Richard W. McLaren, head of the Department's Antitrust Division, said the judgment represented a successful conclusion to a suit filed only eight months ago. He pointed out that the Government had achieved all significant relief sought in the complaint and all that could have been obtained after a full trial. In addition, he said, the Government had obtained certain relief pertaining to auto safety.

Moreover, Mr. McLaren noted that the public benefits of the decree will be realized immediately, instead of after protracted and uncertain litigation.

Main provisions of the proposed judgment are:

The auto manufacturers and the Association are prohibited from restraining in any way the individual decisions of each auto company as to the date when it will install emission control devices, and from restricting publicity about research and development in this field.

They are prohibited from agreeing not to file individual statements with governmental agencies concerned with auto emission and safety standards, and from filing joint statements on such standards unless the governmental agency involved expressly authorizes them to do so.

They are required to withdraw from a 1955 cross-licensing agreement and to grant royalty-free licenses on auto emission control devices under patents subject to the 1955 agreement to all who may request them. The Association is also required to make available all technical reports exchanged by the four auto producers in the past two years under the 1955 agreement.

They are prohibited from agreeing to exchange their companies' confidential information relating to emission control devices or to exchange patent rights covering future inventions in this area.

They are ordered to discontinue their joint assessment or patents on auto emission control devices offered to any of them by outside parties as well as their practice of requiring outside parties to license all of them on equal terms.

The original suit, charging violation of the Sherman Act, said the defendants and others delayed the manufacture and installation of auto emission control devices by agreeing to suppress competition among themselves in the research and development of such devices.

To this end, the suit asserted, they agreed that all industry efforts in this field should be undertaken on a noncompetitive basis; that each would install such devices only simultaneously with the others; and that they would restrict publicity about research efforts in the auto air pollution field.

The complaint charged that on at least three separate occasions the defendants agreed to try to delay the installation of auto emission control devices.

The suit also charged the defendants with having agreed not to compete with each other in the purchase of patent rights covering such devices from outside parties. The suit asserted that the defendants and others had agreed in 1955 to share their patents in this field with each other on a royalty-free basis. In addition, the suit said, they agreed to appraise jointly any patent for an emission control device offered to any one of them by an outside party, and each agreed not to accept a patent license from any outside party without insisting on equal treatment for the others.

Named as co-conspirators in the suit, but not as defendants, were Checker Motor Corporation, Diamond T Motor Car Company, International Harvester Company, Studebaker Corporation, White Motor Corporation, Kaiser Jeep Corporation, and Mack Trucks, Inc.

[United States District Court, Central District of California]

STIPULATION FOR ENTRY OF CONSENT JUDGMENT—CIVIL ACTION No. 69-75-JWC

United States of America, Plaintiff, v. Automobile Manufacturers Association, Inc.; General Motors Corporation; Ford Motor Company; Chrysler Corporation; and American Motors Corporation, Defendants

It is stipulated by and between the undersigned parties, by their respective attorneys, that:

(1) The parties consent that a Final Judgment in the form hereto attached may be filed and entered by the Court at any time after the expiration of thirty (30) days following the date of filing of this Stipulation without further notice to any party or other proceedings, either upon the motion of any party or upon the Court's own motion, provided that plaintiff has not withdrawn its consent as provided herein;

(2) The plaintiff may withdraw its consent hereto at any time within said period of thirty (30) days by serving notice thereof upon the other parties hereto and filing said notice with the Court;

(3) In the event plaintiff withdraws its consent hereto, this Stipulation shall be of no effect whatever in this or any other proceeding and the making of this Stipulation shall not in any manner prejudice any consenting party in any subsequent proceedings.

Dated: September 11, 1969.

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ALLYN O. KREPS,
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[United States District Court, Central District of California]

(CIVIL ACTION No. 69-75-JWC)

(*United States of America, Plaintiff,* v. *Automobile Manufacturers Association, Inc.; General Motors Corporation; Ford Motor Company; Chrysler Corporation; and American Motors Corporation, Defendants*)

FINAL JUDGMENT

The plaintiff, United States of America, having filed its complaint herein on January 10, 1969, and the plaintiff and the defendants by their respective attorneys having severally consented to the entry of this Final Judgment without trial or adjudication of or finding on any issues of fact or law herein and without this Final Judgment constituting evidence or an admission by any of them in respect to any such issue;

Now, therefore, before any testimony has been taken and without trial or adjudication of or finding on any issue of fact or law herein, and upon consent of the parties as aforesaid, it is hereby

Ordered, adjudged and decreed as follows:

This Court has jurisdiction of the subject matter herein and of the parties hereto. The complaint states a claim upon which relief may be granted against the defendants under Section 1 of the Act of Congress of July 2, 1890, entitled "An act to protect trade and commerce against unlawful restraints and monopolies," commonly known as the Sherman Antitrust Act, as amended.

II

As used in this Final Judgment:

(A) "Devices" means air pollution emission control designs, devices, equipment, methods, or parts thereof, for motor vehicles.

(B) "Restricted information" means all unpublished information of the type usually classified as company confidential concerning applied as distinguished from basic research in, or concerning the development, innovation, manufacture, use, sale or installation of Devices. It includes trade secrets, unpublished company policy, and other unpublished technical information for developing, making, improving, or lowering the cost of, Devices by a motor vehicle manufacturer. "Restricted information" shall not mean (i) information concerning basic research in gaining a fuller knowledge or understanding of the presence, nature, amount, causes, sources, effects or theories of control of motor vehicle emissions in the atmosphere, or (ii) information relating primarily to equipment, methods or procedures for the testing or measurement of Devices, or (iii) information for or resulting from the testing or measurement of production prototypes of Devices of an advanced stage exchanged solely for such purposes. Information shall be deemed to be published when it is disclosed without restriction to the public, or to media of general circulation, or to the trade press, or to meetings of stockholders, dealers, or financial analysts, or to meetings of professional, scientific or engineering societies, or committees thereof, the membership of which is not limited to persons employed by defendants or by motor vehicle manufacturers, or to meetings called by representatives of Federal, state or local governments or agencies authorized to issue motor vehicle emission control regulations.

III

The provisions of this Final Judgment shall be binding upon each defendant and upon each of its subsidiaries, officers, directors, agents, servants, employees, successors and assigns, and upon all other persons in active concert or participation with any of them who shall have received actual notice of this Final Judgment by personal service or otherwise, but shall not apply to any transaction between or among a parent company, its subsidiaries, officers, directors, agents, servants and/or employees. Nothing in this Final Judgment shall have any effect with respect to any activities outside the United States which do not adversely and substantially affect the foreign commerce of the United States.

(A) Each defendant is enjoined and restrained from:

(1) Combining or conspiring to prevent, restrain or limit the development, manufacture, installation, distribution or sale of Devices;

(2) Entering into, adhereing to, enforcing or claiming any rights under any provisions of any agreement, arrangement, understanding, plan or program (hereinafter "agreement") with any other defendant or manufacturer of motor vehicles or Devices:

(a) to exchange restricted information;

(b) to cross-license patents or patent rights on Devices which cross-license includes patents or patent rights acquired subsequent to the date of any such cross-license;

(c) to delay installation of Devices or otherwise restrain individual decisions as to installation dates;

(d) to restrict publicity of research and development relating to Devices;

(e) to employ joint assessment of the value of patents or patent rights of any third party relating to Devices;

(f) to require that acquisition of patent rights relating to Devices be conditioned upon availability of such rights to others upon a most-favored-purchaser basis;

(g) to file, in the absence of a written authorization for a joint statement by the agency involved, with any governmental regulatory agency in the United States authorized to issue emission standards or regulations for new motor vehicles or Federal motor vehicle safety standards or regulations, any joint statement regarding such standards or regulations except joint statements relating to (i) the authority of the agency involved, (ii) the draftsmanship of or the scientific need for standards or regulations, (iii) test procedures or test data relevant to standards or regulations, or (iv) the general engineering requirements of standards or regulations based upon publicly available information; provided that no joint statement shall be filed which discusses the ability of one or more defendants to comply with a particular standard or regulation or to do so by a particular time, in the absence of a written agency authorization for such a joint statement, and provided also that any defendant joining in a joint statement shall also file a statement indiviudally upon written request by the agency involved; or

(h) not to file individual statements with any governmental regulatory agency in the United States authorized to issue emission standards or regulations for new motor vehicles or Federal motor vehicle safety standards or regulations.

(B) Nothing in this Final Judgment shall prohibit any defendant:

(1) from furnishing or acquiring any restricted information for the defense or prosecution of any litigation or claim;

(2) from entering into or performing under any otherwise lawful agreement with any other person or conducting *bona fide* negotiations looking to any such agreement:

(a) for the purchase or sale of specific commercial products;

(b) for the license of specific existing patent rights or from including in any such agreement provision for a nonexclusive grant-back of patent rights on improvements obtained by the licensee during the term of the license or a reasonable period thereafter; or

(c) for the purchase, sale or license of specific existing restricted information or specific engineering services relating to Devices or from including in any such agreement provision for a nonexclusive grant-back of patent rights on improvements obtained by the licensee during the term of the license or a reasonable period thereafter; or from furnishing or acquiring any restricted information directly relating thereto:

(3) from entering into, renewing or performing under any otherwise lawful agreement with any nondefendant person, firm or corporation that does not account for more than 2% of world production of motor vehicle passenger car, truck and bus units in the calendar year preceding the entering into or renewing such agreement (See Appendix A); or

(4) from entering into, renewing or performing under any agreement which is submitted in writing to the plaintiff and to which plaintiff consents in writing.

(C) Nothing in Section IV(A)(2)(a) shall prohibit any defendant from engaging in any activity outside the United States reasonably necessary:

(1) to the development of, response to, or compliance with existing or proposed vehicle emission laws, regulations or standards of a foreign governmental body, or

(2) to the performance under any otherwise lawful agreement for the production of motor vehicles outside the United States with any person, firm or corporation not engaged in the production of motor vehicles in the United States at the time of entering into or renewing such agreement.

(A) Each manufacturing defendant is ordered and directed to exercise its right to withdraw from the AMA cross-licensing agreement of July 1, 1955, as

amended, and to take such steps as are necessary to accomplish said withdrawal within one hundred twenty (120) days from the date of entry of this Final Judgment. Notwithstanding such withdrawal defendants may continue to exercise those rights and claims relating to royalty-free licenses under the cross-licensing agreement which have accrued up to the date of entry of this Final Judgment.

(B) Defendant AMA is ordered and directed to relinquish its responsibilities under the AMA cross-licensing agreement of July 1, 1955, as amended, within sixty (60) days from the date of entry of this Final Judgment.

VI

(A) Upon written request therefor and subject to the conditions set forth herein:

(1) Each manufacturing defendant is ordered and directed to grant to any person to the extent that it has the power to do so a nonexclusive, non-transferable and royalty-free license to make, have made, use, lease or sell Devices under any claim of any United States patent or any United States patent application owned or controlled by said defendant or under which it has sublicensing rights, which patent was issued or application was filed prior to the date of entry of this Fnal Judgment and licensed under the AMA cross-licensing agreement of July 1, 1955, as amended, provided that if the manufacturing defendant is obligated to pay royalties to another on the sales of the licensee the license under this paragraph may provide for the payment of those same royalties to the defendant;

(2) Each manufacturing defendant shall grant to any licensee under (1) above, to the extent that it has the power to do so, an immunity from suit under any foreign counterpart patent or patent application for any product manufactured in the United States under the license for sale abroad or for any product manufactured abroad and sold in the United States, provided that if the manufacturing defendant is obligated to pay royalties to another on the sales of the licensee the license may provide for the payment of those same royalties to the defendant; and

(3) Defendant AMA is ordered and directed to make available for examination and copying by any person the technical reports in its possession or control prepared or exchanged by defendants pursuant to said cross-license within two years prior to the entry of this Final Judgment, which are identified in Appendix B; provided that such person agrees to offer each signatory party to the AMA cross-licensing agreement of July 1, 1955, as amended, and any subsidiary thereof a nonexclusive license for a reasonable royalty and upon reasonable terms with respect to any patent or patent application, domestic or foreign, thereafter obtained or filed by such person or under which licensing rights are obtained by such person which is based upon or employs Devices licensed or about which information is supplied pursuant to such license or otherwise under this Section VI(A).

(B) Any existing licensee of any manufacturing defendant shall have the right to apply for and receive a license or licenses under this Final Judgment in substitution for its existing license or licenses from any manufacturing defendant, insofar as future obligations and licenses are concerned. Any licensee shall be free to contest the validity and scope of any licensed patent.

VII

Defendant AMA is ordered and directed to mail a copy of this Final Judgment to all signatories to the AMA cross-licensing agreement of July 1, 1955, as amended, and to all known domestic manufacturers of motor vehicles and motor vehicle engines within thirty (30) days from the date of entry of this Final Judgment, and to issue a press release to the domestic trade and business press relating the substance of the Final Judgment.

VIII

For the purpose of determining or securing compliance with this Final Judgment, duly-authorized representatives of the Department of Justice shall, upon written request of the Attorney General, or the Assistant Attorney General in charge of the Antitrust Division, and on reasonable notice to any defendant made to its principal office, be permitted, subject to any legally recognized privilege, access during the office hours of said defendant to all books, ledgers, accounts, corespondence, memoranda, and other records and documents in the

possession or under the control of said defendant relating to any matters contained in this Final Judgment, and subject to the reasonable convenience of said defendant and without restraints or interference from it, to interview officers or employees of said defendant, who may have counsel present, regarding any such matters. Said defendant, upon the written request of the Attorney General or the Assistant Attorney General in charge of the Antitrust Division, shall submit such written repors with respect to any of the matters contained in this Final Judgment as from time to time may be requested. No information obtained by the means provided in this Section shall be divulged by any representative of the Department of Justice to any person other than a duly authorized representative of the Executive Branch of the plaintiff, except in the course of legal proceedings to which the United States is a party for the purpose of securing compliance with this Final Judgment or as otherwise required by law.

IX

Section IV(A)(2) (a) and (g) of this Final Judgment shall expire ten years after the date of entry hereof, provided that plaintiff may apply to this Court for the continuation of one or both of said provisions, such application to be made not later than nine years after the date of entry of this Final Judgment.

X

Jurisdiction of this cause is retained for the purpose of enabling any of the parties to this Final Judgment to apply to this Court at any time for such further orders and directions as may be necessary or appropriate in relating to the construction of or carrying out of this Final Judgment, for the modification or vacating of any of the provisions thereof, and for the purpose of the enforcement of compliance therewith and the punishment of violations thereof.

JESSE W. CURTIS,
U.S. District Judge.

APPENDIX A

Section IV(B)(3) of this judgment was prepared in reliance on the motor vehicle production statistics set forth in the following tables contained in Wards 1969 Automotive Yearbook (31st edition) published by Powers and Company, Inc., Detroit, Michigan, at page 14:

1968 WORLD MOTOR VEHICLE PRODUCTION

[20 leading countries]

	Passenger cars	Trucks and buses	1968 total	1967 total
United States	8,843,031	1,950,713	10,793,744	8,992,269
Canada	900,527	277,649	1,178,176	943,992
Total	9,743,558	2,228,362	11,971,920	9,936,261
Japan	2,055,821	2,030,005	4,085,826	3,146,486
West Germany	2,535,433	571,525	3,106,958	2,482,319
United Kingdom	1,815,000	409,300	2,224,300	1,937,119
France	1,833,047	242,570	2,075,617	2,009,672
Italy	1,544,933	118,716	1,633,649	1,542,669
Argentina	127,965	53,011	180,976	175,318
Australia	340,000	75,000	415,000	390,119
Austria	2,200	2,350	4,550	4,383
Brazil	158,863	118,371	277,234	225,300
India	37,000	41,000	78,000	69,000
Netherlands	60,000	7,000	67,000	56,566
Mexico	102,907	37,192	140,099	123,751
Poland	40,500	39,600	80,100	61,400
Spain	311,531	81,902	393,433	362,906
Sweden	223,330	21,361	244,691	214,560
Czechoslovakia	126,000	50,200	176,200	164,000
Yugoslavia	50,400	13,680	64,080	60,000
U.S.S.R.	250,000	550,000	800,000	728,900
Total	11,614,930	4,462,783	16,077,713	13,754,468
Grand total	21,358,488	6,691,145	28,049,633	23,690,729

Note: Data for above tabulation drawn from best sources available. Statistics for some Red-bloc countries based upon monthly averages and are subject to slight change. U.S.S.R. for 1968 is an estimate based upon final 1967 counts.

WORLD MOTOR VEHICLE PRODUCTION—1968

[26 leading manufacturers]

Ranking	Manufacturer	Country	Cars	Trucks	Total 1968	Total 1967
1	GM	United States	4,592,077	828,978	5,421,055	4,798,301
2	Ford	do	2,396,924	623,272	3,020,196	2,122,841
3	Chrysler	do	1,585,501	173,760	1,759,360	1,505,561
4	Volkswagen	West Germany	1,448,533	100,400	1,548,933	1,162,258
5	Fiat	Italy	1,301,751	89,470	1,391,221	1,312,215
6	Toyota	Japan	659,189	438,216	1,097,405	832,130
7	BLM	England	807,067	179,204	986,271	646,318
8	Nissan	Japan	571,614	408,220	979,834	726,067
9	Renault	France	731,000	76,000	807,000	777,468
10	British Ford	England	553,701	108,017	661,718	526,987
11	Opel (GM)	West Germany	646,718	10,000	656,718	549,281
12	Toyo Kogyo	Japan	178,1(5	282,994	461,100	388,323
13	Citroen	France	383,000	77,600	460,600	500,030
14	Ford	Canada	287,286	157,815	445,101	295,779
15	GM	do	338,016	86,228	424,304	394,919
16	Peugeot	France	377,725	29,980	407,705	405,314
17	Mitsubishi	Japan	130,253	229,723	359,976	317,378
18	GM Vauxhall	England	244,918	97,222	342,140	290,706
19	Ford Cologne	West Germany	306,232	28,923	335,155	396,646
20	Honda	Japan	186,560	132,257	318,817	149,289
21	Chrysler Simca	France	317,248	0	317,248	248,574
22	Daimler-Benz	West Germany	216,000	68,837	284,837	254,138
23	AM Corp	United States	268,439	0	268,439	229,058
24	D. Kogyo	Japan	89,296	171,059	260,355	225,490
25	Chrysler	Canada	219,151	16,573	235,724	202,812
26	Chrysler Rootes	England	189,102	27,066	216,168	203,312

Note: Because both production and factory sales are used in the above tabulation, the above rankings are not absolute and could vary slightly. Data used represents vehicles produced in the indicated locations. Fiat excludes Autobianchi, Volkswagens excludes Auto Union. BLM was formed in 1968, hence its 1967 total represents BMC.

It is contemplated by the parties that Ward's Automotive Yearbook or any successor publication will be the source of the statistics necessary to the future interpretation of the provisions of Section IV(B)(3)

APPENDIX B

Pursuant to Section VI(A)(3) of the Final Judgment the following technical reports are identified:

SUBCOMMITTEE REPORTS TO THE VEHICLE COMBUSTION PRODUCTS COMMITTEE, JANUARY 1968

1. Atmospheric Chemistry Panel Report
2. Diesel Emission Panel Report

(a) Proposed Standards for Motor Vehicle Exhaust Odor and Irritation—California Department of Public Health Bureau of Air Sanitation—March 1, 1966—8 pages

(b) Proposed Additions to the California Administrative Code—Standards for Motor Vehicle Emissions, State Board of Public Health Meeting June 10, 1966—prepared by the State of California Department of Public Health—May 4, 1966—6 pages

3. Ad Hoc Engine Deposits Panel Report

(a) A Proposed Program to Establish the Effect of Combustion Chamber Deposits on Exhaust Emissions—prepared by Engine Deposit Panel—January 3, 1967—19 pages.

(b) Proposed Joint AMA—API Engine Deposits Program—September 14, 1967—7 pages

4. Engine and Vehicle Modification Panel Report
5. Exhaust Emission Measurement Panel Report

(a) EEMP—Status Report on Future Exhaust Emission Standards—undated—8 pages

6. Ad Hoc Group on Exhaust System Heat Report
7. Fuel System Emission Panel Report

(a) FSEP—Report of Fuel System Emission Panel to VCP—July 20, 1967—9 pages

(b) AMC Evaporation System—undated—6 pages

(c) Chrysler Closed Vent System—C.V.S.—prepared by Chrysler—undated—8 pages

(d) Crankcase Storage of Evaporative Emissions—prepared by General Motors Corp.—October 25, 1967—9 pages

(e) Charcoal Canister Evaporative Emission Control System—prepared by General Motors Corp.—October 25, 1967—9 pages

(f) History of Evaporative Control Studies—prepared by Ford Motor Company—December 1, 1967—12 pages

(g) Crankcase Storage System for Control of Fuel Evaporative Emissions—prepared by Ford Motor Company—December 1, 1967—14 pages

(h) Carbon Air Cleaner Evaporative Control System—prepared by Ford Motor Company—December 1, 1967—9 pages

8. Ad Hoc Health Committee Report

9. Heavy Vehicle Panel Report

(a) Differences between California and HEW Truck Test Cycles—prepared by Heavy Truck Panel—June 6, 1967—3 pages

10. New Devices Committee Report

11. Ad Hoc Traffic Survey Panel Report

(a) Comparison of General Durability Schedules—prepared by Ad Hoc Traffic Survey Panel—undated—1 page

12. Vehicle Emission Surveillance Panel Report

(a) Analysis of California Surveillance Data—prepared by the Auto Club of Southern California and Scott Research Laboratories—dated April 20, 1967—8 pages

Subcommittee Reports to the Vehicle Combustion Products Committee, May 23, 1968

1. Atmospheric Chemistry Panel Interim Report

2. Engine and Vehicle Modification Panel Interim Report

3. Exhaust Emission Measurement Panel Interim Report

(a) State of California Air Resources Board—Specification for Simplified Instrument Console for Emission Measurements—13 pages—December 27, 1967

(b) State of California Air Resources Board—Test Procedure for Approval of Instruments for Garages, Vehicle Assembly Line and Field Station Use—March 6, 1968—8 pages

4. Fuel System Emission Panel Interim Report

(a) Laboratory Crosscheck Charts—undated—5 pages

5. Heavy Vehicles Panel Interim Report

(a) 1969 California Exhaust Emission Standard and Test Procedure for Heavy Trucks contained in the Federal Register publication of January 4, 1968—23 pages

6. Ad Hoc Traffic Survey Panel Interim Report

(a) Considerations in Traffic Survey and Test Cycle Development—NCAPC Meeting of March 29, 1968—prepared by the Ad Hoc Traffic Survey Panel—April 5, 1968—2 pages

7. Vehicles Emission Surveillance Panel Interim Report

(a) Hot vs. Cold Start Surveillance Testing—prepared by VESP—March 27, 1968—2 pages

(b) VESP Future Surveillance Program—undated—2 pages

(c) Summary of Analysis—undated—5 pages

(d) VESP reply letter (draft) to Mr. John Raymond of CMVPCB—May 7, 1968

(e) Effect of Tune-Up—undated—2 pages

8. Engine and Vehicle Modification Panel Reports

(a) 1970 California Evaporative Control Standard and Test Procedure for Passenger Cars contained in the Federal Register of January 4, 1968—23 pages

(b) Intake Valve Throttling (IVT)—A Sonic Throttling Intake Valve Engine—prepared by General Motors for the SAE meeting—May 20-24, 1968—11 pages

(c) EVMP—Present Status of Steam Power for Road Vehicles—May 8, 1969—11 pages

(d) Preliminary Test Results with Non-Flame After Burner Exhaust Manifold F4-134 cu. in. Engine—prepared by KAISER Jeep CORPORATION—May 8, 1968—5 pages

(e) Ad Hoc Subpanel—Valve Timing Proposal Submitted to EVMP—April 9, 1968—2 pages

SUBCOMMITTEE REPORTS TO THE VEHICLE COMBUSTION PRODUCTS COMMITTEE, SEPTEMBER 27, 1968

1. Atmospheric Chemistry Panel Interim Report
2. Diesel Emission Panel Interim Report
3. Engine and Vehicle Modification Panel Interim Report
(a) Report on New Engine Idle Stability—prepared by EVMP members—September 10, 1968—18 pages
(b) Driveability Procedure—August 6, 1968—8 pages
(c) Vehicle Inspection Procedure for Emission Control Systems and Devices, Gasoline Powered Vehicles—Inspection Old Format—August 1, 1967—5 pages; Inspection—New Format—5 pages
(d) Mass Flow Data—prepared by Chrysler Corporation—September 10, 1968—11 pages
(e) EVMP Panel Report on 1968 Engine Idle Setting Procedures—July 10, 1968 Revision including Shop Manual Instructions Furnished by several member companies
(f) EVMP Valve Timing Proposal—undated—2 pages
(g) Excerpt from EVMP Memorandum Report dated June 11, 1968 on Catalytic Converters and Afterburners—1 page
(h) Catalytic Converters for Emission Control—prepared by Toyota Motor Company—August 6, 1968—8 pages
(i) Ceramic Exhaust Manifold Reactors—prepared by Ford Motor Company—August 5, 1968—7 pages
4. Exhaust Emission Measurement Panel Interim Report
(a) Status Report on Assembly Line Testing by EEMP—August 5, 1968—2 pages
(b) Report on Measurement Procedure for Nitric Oxide for California—1970 by EEMP—August 5, 1968—16 pages
(c) Report on Exhaust Emission Reactivity Criterion from the Atmospheric Chemistry panel and the EEMP—July 30, 1968—6 pages
(d) Proposal—Exhaust Emission *Correlation Program HEW*—AMA Laboratories—prepared by EEMP Panel member—October 24, 1967—4 pages
(e) Fast Response Flame Ionization Instrument—letter prepared by Chrysler Corporation—dated June 19, 1968—2 pages
(f) Bay Toll Crossing Letter—*answer sent to* Mr. E. R. Foley by Mr. Sherman—August 21, 1968 with attachments—7 pages
5. Fuel System Emission Panel Interim Report
(a) Fuel System Emission Panel report on Proposed Test Procedure for the Determination of Liquid Fuel Losses from Vehicle Fuel Tanks—September 27, 1968—8 pages
(b) Fuel System Emission Panel report on Proposed Program for Circulation and Cross-Check of 1970 Evaporative Cars—September 27, 1968—2 pages
6. Heavy Vhicle Panel Interim Report
(a) Recommended Application Procedure for Certification of New Gasoline Engines for Use in Heavy Duty Vehicles 1970 Model Year—prepared by the National Air Pollution Control Administration—dated September 28, 1968—19 pages
7. Ad Hoc Traffic Survey Panel Interim Report
8. Vehicle Emission Surveillance Panel Interim Report

SUBCOMMITTEE REPORTS TO THE VEHICLE COMBUSTION PRODUCTS COMMITTEE, DECEMBER 10, 1968

1. Atmospheric Chemistry Panel Interim Report
2. Engine & Vehicle Modification Panel Interim Report
(a) Driveability Demonstration—prepared by the Driveability Subpanel *to* EVMP—November 4, 1968—14 pages
(b) Summary—1968 Emission Control Systems as presented by the companies to the Engine and Vehicle Modification Panel—undated—12 pages
(c) Comments to ESC by the EVMP on the Feasibility of a Two Minute Emission Inspection System—October 14, 1968—3 pages
(d) AMA Recommendations in *AMA Inspection Handbook*, Section IX Vehicle Control Systems—5 pages—dated September 10, 1968
(e) Report of visit to New Jersey Inspection Station November 21, 1968—by the EVMP—7 pages

(f) Comments to ESC from EVMP on California Proposals for Emission Control Standards on 1970 and Later Model Vehicles—October 21, 1968—5 pages

3. Exhaust Emission Measurement Panel Interim Report

(a) EEMP comments and Recommendations to AMA ESC on California AB 357 Requirements for Assembly Line Testing for Vehicle Emissions—December 2, 1968—10 pages

(b) Letter from EEMP of September 6, 1968 to Mr. K. D. Mills at Willow Run and Mr. Mills answer of October 14, 1968 re AMA Exhaust Emission Measurement Correlation Program

(c) Comments to ESC by the EVMP on the Feasibility of a Two Minute Emission Standards Committee on Measuring Evaporative Losses—undated—4 pages

(d) Recommended Application Procedure for Certification of New Gasoline Engines for Use in Heavy Duty Vehicles—1970 Model Year—prepared by National Air Pollution Control Administration—September 23, 1968—19 pages

4. Fuel System Emission Panel Interior Report

5. Heavy Vehicle Panel Interim Report

6. Ad Hoc Traffic Survey Panel Interim Report

SUBCOMMITTEE REPORTS TO THE VEHICLE COMBUSTION PRODUCTS COMMITTEE, MARCH 27, 1969

1. Engine & Vehicle Modification Panel Interim Report

2. Exhaust Emission Measurement Panel Interim Report

(a) Report from Exhaust Emission Measurement Panel on California ARB proposed Assembly Line Test Procedure for Motor Vehicle Exhaust—January 28, 1969—6 pages

(b) Effect of Engine Intake Air Moisture on Nitrogen Oxides Emissions—prepared by Ethyl Corporation, March 14, 1969—23 pages

(c) Humidity Correction K Factor—prepared by Nissan Motor Company—undated—16 pages

(d) Mass Emission Test Procedures—undated—4 pages

(e) Effect of Fuel Composition (% Aromatics) on Exhaust Hydrocarbon Concentration—Based Upon DuPont data and a Report by GM dated January 22, 1969—5 pages

(f) Report on Measurement Procedure for Nitric Oxide for California—1970—prepared by EEMP—August 5, 1968—16 pages

(g) Critique—California AB 690 Test Method for Measuring Vehicle Exhaust Emissions on a Mass Basis—undated—4 pages

3. Fuel System Emission Panel Interim Report

4. Health Committee Interim Report

5. Heavy Vehicle Panel Interim Report

6. Ad Hoc Traffic Survey Interim Report

SUBCOMMITTEE REPORTS TO THE VEHICLE COMBUSTION PRODUCTS COMMITTEE, JUNE 19, 1969

1. Heavy Vehicle Panel Interim Report

2. Atmospheric Chemistry Panel Interim Report

(a) Exhaust Emission Reactivity Criterion—prepared by the Atmospheric Chemistry Panel and the EEMP—May 28, 1969—6 pages

3. Vehicle Emission Surveillance Panel Interim Report

(a) Surveillance Data Summary—prepared by VESP—June 9, 1969—5 pages

4. Exhaust Emission Measurement Panel Interim Report

(a) Proposed Items of Discussion on May 12, 1969 at Willow Run—prepared by Messrs. Mick, Fagley, and Hagen—8 pages

(b) Analysis of AMA data for HC Emissions during the Federal Cycle—prepared by Ethyl Corporation—June 2, 1969—8 pages

(c) Analysis of AMA data for HC Emissions during the California Cycle tests—Changes to improve Response Time—prepared by Chrysler Corporation—April 29, 1969—3 pages

(d) Proposal Exhaust Emission Correlation Program HEW—AMA Laboratories—prepared by Ford Motor Company—April 7, 1969—4 pages

5. Engine & Vehicle Modification Panel Interim Report

(a) Transmission Controlled Spark—An Evaluation of NOX Emissions—prepared by General Motors Corporation—April 15, 1969—10 pages

(b) Presentation on the Effect of Valve Overlap on Oxides of Nitrogen Emissions—prepared by General Motors Corporation—undated—6 pages

(c) IH Spark Advance Monitoring System—prepared by International Harvester Company—March 4, 1969—4 pages
(d) Performance of a Catalytic Converter on Non-leaded Fuel prepared by General Motors Corporation and published in SAE—undated—13 pages
(e) Comments on Performance of a Catalytic Converter on Non-leaded Fuel—prepared by Ford Motor Co.—presented before the SAE mid Year Meeting May 22, 1969—18 pages
(f) Panel Charge—prepared by J. P. Charles—dated May 27, 1969—1 page
(g) Engine Tune-up Data for 1970 Year Model Toyota Vehicles—prepared by Toyota Motor Company dated June 10, 1969—2 pages
(h) Engine Idle Setting Procedure—prepared by KAISER Jeep CORPORATION—undated—1 page
(i) Committee Correspondence re New Jersey Vehicle Emission Inspection—dated April 7th, May 8th, June 9th, 1969 describing telephone conversation with Mr. Elston
(j) Inspection Handbook Distribution—dated June 4, 1969.
(k) Quality Car Care Schedule—prepared by Toyota Motor Company—undated—3 pages
(l) Layman's Nomenclature—undated—2 pages
6. Fuel System Emission Panel Interim Report
(a) Laboratory Cross-Check Program—prepared by Fuel System Emission Panel—May 5, 1969—11 pages
(b) Fuel Tank Heating Methods—prepared by Fuel System Emission Panel—May 5, 1969—22 pages
(c) Emission Control Calculations on Total Motor Vehicle HC & CO Emissions—dated June 17, 1969—3 pages

ADDITIONAL SUBCOMMITTEE REPORTS TO THE VEHICLE COMBUSTION PRODUCTS COMMITTEE, IN PREPARATION AND TO BE COMPLETED BY OCTOBER 31, 1969

1967 annual report of Engine & Vehicle Modification Panel

1. Status Report No. 5 of the Engine & Vehicle Modification Panel to the Vehicle Combustion Products Committee—1967—27 pages
2. Tables I and II on 6 Cylinder and 8 Cylinder Camshafts
Figure 1. American Motors Report on 6 Cylinder Camshafts—1 page
Figure 2. Field Survey of Combusition Testers
Figure 3. Response to Exhaust Gas with and without Air Injection using a Johnson-Williams Combustible Analyzer
Figure 4. Variable Dilution System—Exhaust Gas (missing)
Figure 5. Blow-by Emission Measurement—prepared by New Jersey State Department of Health
Figure 6. 1968 Engine Information Decals
Figure 7. Cross Section of 199 C.I.D. Combustion Chamber—Quench and Low Quench
Figure 8. Cross Section of 232 C.I.D. Combustion Chamber—Quench and Low Quench
Figure 9. Head Gasket Bore Configuration user with Low Quench Engines 199 and 232 C.I.D.
Figure 10. Effect of Air-Fuel Ratio on Exhaust NO Concentrations for Various Speed-Load Combinations
Figure 11. Effect of Spark Timing on Exhaust NO Concentrations for Various Speed-Load Combinations
Figure 12. Effect of Intake Manifold Vacuum on Exhaust NO Concentrations for Various Air-Fuel Ratios
Figure 13. Effect of Coolant Temperature on Exhaust NO Concentrations for Duplicate Runs
3. Appendices:
(A) Camshaft and Valve Timing—EVMTG Proposal
(B) Proposed AMA Engine Idle Setting Procedures—EVMPTG June 27, 1967
(C) Reply to New Jersey Regarding State Vehicle Inspection by VCP—November 10, 1967
(D) Reply to Air Pollution Control Administration—December 22, 1966
(E) Bibliography of Papers on Emission Control Devices Submitted to EVMP by Member Companies

1968 annual report of engine & vehicle modification panel

1. Status Report No. 6 of the Engine and Vehicle Modification Panel to the Vehicle Combustion Products Committee—1968—23 pages

2. Appendices:

(A) Control of Oxides of Nitrogen—Chrysler Study Curves, data, and Sketches Illustrating Chrysler Studies in NO control.

(B) Exhaust System Devices for Emission Control—International Harvester Company.

(C) Vehicle Inspection Procedures

(D) 1969 Emission Control Systems

(E) Mass Flow

(F) Idle Setting Procedures—A detailed description of the shop manual procedures for each manufacturer

(G) Manifold Reactors—Preliminary Test Results with NonFlame After Burner Exhaust Manifold, F4–134 cu. in Engine

(H) Air Injection Modifications—Toyota Motor Co., Ltd. Nippon Denso, Co., Ltd.

(I) Steam-Powered Road Vehicles—Present Status

(J) Valve Timing Proposal

(K) Driveability—Driveability Demonstration

(L) Comments on California 1970 Proposals

ENGINE AND VEHICLE MODIFICATION PANEL REPORTS

Date of presentation	Subject	Prepared by	Number of pages
1. Oct. 17, 1967	Combustion chamber quench changes, 1968 models.	Chrysler Corp	1
2. Oct. 17, 1967	1968 Ford emissions systems	Ford Motor Co	1
3. Oct. 17, 1967	Idle adjustments	Chrysler Corp	1
4. Oct. 17, 1967	Idle mixture, effect of miles on idle speed, and timing changes.	General Motors Corp	3
5. Oct. 17, 1967	Emission control by engine design and development.	American Motors Corp	17
6. Nov. 15, 1967	New Jersey emissions inspection program	EVMP	10
7. Nov. 17, 1967	Engine idle-setting procedures	American Motors, Chrysler Corp., Ford Motor Co., General Motors Corp., International Harvester Co., Kaiser Jeep Corp.	37
8. Dec. 5, 1967	Changes in idle speed re mixture	Ford Motor Co	2
9. Dec. 5, 1967	Emission-control labels	Kaiser Jeep Corp	1
10. Dec. 5, 1967	AMA–HEW exhaust flow equations	EVMP	5
11. Jan. 2, 1968	Idle service instruction—CAS	Chrysler Corp	1
12. Jan. 2, 1968	Exhaust volume measurements on cycle tests	do	1
13. Dec. 5, 1967	Survey of emission control devices in use of 1968 models.	American Motors, Chrysler Corp., Ford Motor Co., General Motors Corp.	17
14. January 1968	Exhaust emission-control devices	Kaiser Jeep Corp	2
15. Jan. 4, 1968	Idle mixture, speed and spark timing adjustments.	General Motors Corp	6
16. Jan. 2, 1968	Exhaust system devices for emission control	International Harvester Co	1
17. Jan. 2, 1968	Exhaust manifold reactors	do	3
18. Jan. 2, 1968	Heavy truck emission-control systems	do	2
19. Dec. 15, 1967	Adjusting idle mixture	Ford Motor Co	7
20. Feb. 13, 1968	Changes in idle tune during first 1,000 miles 1968 GM cars.	General Motors Corp	1
21. Feb. 2, 1968	Decal code	Crysler Corp	3
22. Feb. 9, 1968	Test data on catalytic system	Kaiser Jeep Corp	3
23. Feb. 13, 1968	Ceramic exhaust manifold reactors	Ford Motor Co	4
24. Feb. 13, 1968	Test data exhaust emissions	Kaiser Jeep Corp	1
25. Mar. 12, 1968	Air control valve to improve running stability after starting on an air injected gasoline engine.	Toyota Motor Co., Ltd., Nippon Denso Co. Ltd.	7
26. Mar. 12, 1968	Engines for Toyota 1968 models	Toyota Motor Co., Ltd	1
27. Mar. 12, 1968	Engine stalling on deceleration	Nissan Motor Co., Ltd	7
28. Mar. 12, 1968	Surface to volume ratio 4 cylinder vehicle	Kaiser Jeep Corp	1
29. Apr. 4, 1968	Data on idle stability and exhaust gas volume of vehicles.	Toyota Motor Co., Ltd	5
30. Apr. 9, 1968	Mass flow data	Nissan Motor Co., Ltd	1
31. Apr. 4, 1968	Idle settings, 4,000 miles or under	Chrysler Corp	1

ENGINE AND VEHICLE MODIFICATION PANEL REPORTS—Continued

Date of presentation	Subject	Prepared by	Number of pages
32. May 8, 1968	Report on present status with steam powered road vehicles and their emission characteristics.	EVMP (attachments A5, B3, C2, and D1).	
33. May 8, 1968	Preliminary test results with nonflame afterburner exhaust manifold F–4—134 cubic inch engine.	Kaiser Jeep Corp	
34. May 8, 1968	Valve timing proposal submitted to EVMP	Kaiser Jeep Corp., General Motors Corp., Ford Motor Co.	2
35. June 11, 1968	1968 engine idle setting procedures	American Motors Corp., Chrysler Corp., Ford Motor Co., General Motors Corp., International Harvester Co., Nissan Motor Co., Toyota Motor Co.	7
36. June 11, 1968	Vehicle inspection procedure for emission control systems and devices, gasoline powered vehicles.	American Motors Corp., Ford Motor Co., General Motors Corp., International Harvester Co., Kaiser Jeep Corp., Toyota Motor Co., Ltd.	2
37. July 10, 1968	1968 idle setting procedures shop manual instructions.	American Motors Corp., Chrysler Corp., Ford Motor Co., General Motors Corp., International Harvester Co., Kaiser Jeep Corp., Nissan Motor Co., Ltd., Toyota Motor Co., Ltd.	35
38. Aug. 6, 1968	Driveability procedure	EVMP	5
39. Aug. 6, 1968	Valve timing proposal	EVMP	8
40. Aug. 6, 1968	Catalytic converter for emission control	Toyota Motor Co., Ltd	8
41. Aug. 5, 1968	Ceramic exhaust manifold reactor	Ford Motor Co	7
42. Aug. 6, 1968	Throttle positioner	Toyota Motor Co., Ltd	20
43. Aug. 21, 1968	Valve timing	EVMP	2
44. Sept. 10, 1968	Report on new engine idle stability	Ford Motor Co., American Motors Corp., General Motors Corp., Toyota Motor Co., Ltd., Chrysler Corp., International Harvester Co., Nissan Motor Co., Ltd.	25
45. Aug. 27, 1968	Emission inspection presentation to AAMVA on vehicle emission inspection.	ESC chairman	18
46. Sept. 10, 1968	Mass-flow data	Chrysler Corp	12
47. Aug. 22, 1968	Rating idle quality	International Harvester Co	8
48. Aug. 16, 1968	Vehicle evaluation rating system	Ford Motor Co	2
49. Aug. 9, 1968	Idle quality evaluations	American Motors Corp	2
50. Sept. 7, 1968	Engine idle stability evaluation procedure	Nissan Motor Corp	2
51. Sept. 10, 1968	Exhaust manifold reactors	International Harvester Co	4
52. September 1968	do	Nippon Denso Co., Ltd	3
53. Oct. 8, 1968	1969 emission control systems	Toyota Motor Co., Ltd	2
54. Oct. 10, 1968	AMA drivability demonstration	EVMP	12
55. Oct. 7, 1968	1969 emission control systems	American Motors Corp	1
56. Oct. 8, 1968	1969 Chrysler cleaner air system compared to the 1968 system.	Chrysler Corp	3
57. Oct. 8, 1968	1969 emission control systems	Ford Motor Co	3
58. Nov. 1, 1968	Summary of 1969 GM exhaust emission control systems.	General Motors Corp	1
59. Nov. 12, 1968	1969 emission control systems	International Harvester Co	1
60. January 1969	Exhaust emission control systems	Kaiser Jeep Corp	1
61. Dec. 17, 1968	Control systems for 1970	American Motors Corp	5
62. Dec. 17, 1968	Chrysler 1970 emission controls	Chrysler Corp	5
63. Dec. 17, 1968	1970 emission-control systems	Ford Motor Co	4
64. Dec. 17, 1968	*Summary of proposed 1970 emission-control systems.*	General Motors Corp	7
65. Dec. 17, 1968	1970 light duty vehicle prototype emission control systems.	International Harvester Co	11
66. November 1968	Projected vehicle emission control system for Toyota 1970 model vehicles.	Toyota Motor Co., Ltd	27
67. Dec. 17, 1968	Control of oxides of nitrogen	Chrysler Corp	9
68. Dec. 17, 1968	Inspection of emission-control systems	General Motors Corp	3
69. Dec. 17, 1968	Supplementary information on 1969 emission-control systems.	International Harvester Co	7
70. Jan. 7, 1969	Investigations of NO_x control systems	Ford Motor Co	35
71. Jan. 7, 1969	Oxides of nitrogen from smaller gasoline engines	Toyota Motor Co., Ltd	63
72. Jan. 7, 1969	Summary of proposed 1970 emission-control systems.	Kaiser Jeep Corp	5
73. December 1968	The effects of the ignition system on exhaust emissions.	Mitsubishi Electric Corp	26
74. Mar. 24, 1969	Engine idle quality test procedure of Toyota	Toyota Motor Co., Ltd	6
75. Mar. 27, 1969	Reduction of nitrogen oxides in automobile exhaust	Nippon Denso Co., Ltd	11
76. Mar. 11, 1969	*Description of ignition advance monitoring systems*	International Harvester Co	5
77. June 10, 1969	Engine idle setting procedure	Kaiser Jeep Corp	3
78. May 13, 1969	Quality car care schedule	Toyota Motor Co	3
79. May 19, 1969	Performance of a catalytic converter on nonleaded fuel SAE paper No. 690503.	General Motors Corp	10
80. May 22, 1969	Comments by J. H. Jones & E. E. Weaver—car systems research on SAE paper No. 690503.	Ford Motor Co	18

EXHAUST EMISSION MEASUREMENT PANEL REPORTS

Date of presentation	Subject	Prepared by	Number of pages
1. Sept. 8, 1967	A proposal for an interim mass exhaust emission test procedure.	Ford	3
2. Sept. 8, 1967	A proposal for 1970 studies based on mass equivalents.	General Motors	4
3. Sept. 7, 1967	Calculations of exhaust mass emissions	do	2
4. Sept. 8, 1967	Interim mass emission test procedure (Sept. 21, 1967) EEMP to VCP.	EEMP	8
5. Oct. 25, 1967	Proposal—exhaust emission correlation program for EEMP.	Ford	4
6. Nov. 20, 1967	Curves and tables emissions versus vehicle weight	Chrysler	17
7. Nov. 20, 1967	Interim mass standards for 1970	General Motors	4
8. Nov. 20, 1967	Assumptions for 1970 certification based on mass	Ford	3
9. Nov. 20, 1967	Curves—F^3/cycle versus engine displacement—inertia weight.	American Motors	3
10. Jan. 18, 1968	EEMP notes to ESC on HEW studies published Jan. 4, 1968.	EEMP	18
11. Jan. 31, 1968	EEMP proposed revision of Cal. specifications for assaying line instrument.	EEMP	14
12. Mar. 13, 1968	Computer print-out of best fit equation for Cal. gases.	General Motors	4
13. Mar. 13, 1968	Propane response	do	1
14. Mar. 13, 1968	FIA of propane Cal. gases using olson gravimetric standards.	EEMP	1
15. Mar. 13, 1968	Daimler-Benz response to HEW 1970 standards dated Jan. 4, 1968.	Mercedes-Benz	11
16. Mar. 29, 1968	Considerations in traffic survey and test cycle development.	TSP	3
17. Apr. 17, 1968	Effect of emission control system on reactivity	Ford	3
18. Apr. 17, 1968	Relative efficiencies of control systems—table	Chrysler	1
19. May 9, 1968	Report on variable dilution sampling—Clark	General Motors	8
20. May 9, 1968	Report on NO_x measurement—Lang	do	13
21. May 9, 1968	Production line test—instrument and test procedure.	American Motors and California ARB staff.	1
22. May 28, 1968	Table—spread between NDIR and FID analyses	American Motors	2
23. May 28, 1968	Comparison between 7-mode and 10-mode cycle NDIR versus FID.	International Harvester	5
24. May 28, 1968	Whittaker method of measuring NO—strip chart	Chrysler	2
25. May 28, 1968	Proposed answer to Cal. Bay Toll Crossing Division.	EEMP	7
26. June 5, 1968	Strip chart of NO measurement using Whittaker method—letter from Whittaker to W. Fagley, Jr.	Chrysler	4
27. July 23, 1968	European consideration of atmospheric pollution problems.	AMA	3
28. July 17, 1968	Comparison of emission reactivities—table 1	General Motors	1
29. July 17, 1968	Number of hydrocarbons evaluated under conconditions.	do	1
30. July 17, 1968	Graphs plus computer summaries—HC reactivity versus conc. by C. G.	do	15
31. July 17, 1968	Comparison—HC conc. by C. G. versus FID	do	3
32. July 17, 1968	Correlation—reactivity and gas chromotography	Ford	1
33. July 17, 1968	SAE paper 680419—FID technique—HC in diesel exhaust.	International Harvester	15
34. July 17, 1968	Correlation between 7-mode and USPHS 10-mode cycles—Clark.	General Motors	9
35. July 17, 1968	Schematic diagram—NO and O_2 instrument console.	do	1
36. July 17, 1968	Relative sensitivity—FID analyzer	Chrysler	2
37. July 30, 1968	Measurement procedure—NO for California, 1970	EEMP	16
38. July 30, 1968	Background data for calculating NO_x for California	Chrysler	3
39. July 30, 1968	Correlation program—HEW-AMA Labs—Westveer	EEMP	4
40. July 30, 1968	Report on reactivity to ESC from joint ACP and EEMP.	EEMP	6
41. Aug. 5, 1968	Report on measurement procedure for NO California, 1970.	EEMP	15
42. Sept. 11, 1968	Continuous Trace—Rate of exhaust flow, 10-mode cycle.	Chrysler	3
43. Sept. 11, 1968	Mass flow data—Fagley (7-versus 10-mode cycles)	do	14
44. Sept. 11, 1968	Letter—Jensen to Maga—Mass emission measurement technique.	AMA	3
45. Sept. 11, 1968	Table—Fuel measured mass compared with calculated Federal standard mass.	Chrysler	1
46. Sept. 11, 1968	Repeatability of no measurement technique—9 vehicles.	General Motors	6
47. Dec. 3, 1968	Comments to ESC on California law AB 357—Assembly-line test.	EEMP	11
48. Jan. 27, 1969	Report on NO_x humidity factor—Maeda	Nissan	16
49. Jan. 27, 1969	EEMP to ESC report on California ARB assembly line test.	EEMP	6
50. Feb. 5, 1969	European driving cycle—Report by F. Louis	Renault	
51. Feb. 18, 1969	Exhaust-flow method of mass measurement—Fagley.	Chrysler	19

EXHAUST EMISSION PANEL REPORTS—Continued

Date of presentation	Subject	Prepared by	Number of pages
52. Feb. 18, 1969	Mass emission program—Nick	General Motors	33
53. Mar. 4, 1969	Comments on California proposed assembly line test procedures.	Toyota	5
54. Mar. 18, 1969	Effect of moisture on NO_x emissions	Ethyl	24
55. Mar. 20, 1969	Effect of fuel composition—on FID/NDIR ratio—Campau.	Ford	11
56. Mar. 26, 1969	Reduction of NO_x manifold reactor—Tanaka et al.	Nippon Denso	12
57. Apr. 11, 1969	Exhaust emission measurement correlation program—Westveer.	EEMP	4
58. Apr. 14, 1969	Supplement—moisture on NO_x-RK factor calculation.	Ethyl	2
59. Apr. 21, 1969	Comments on foreign cycles—Lombardi	EEMP	3
60. Apr. 30, 1969	HC measurement by FID—improved response—Teague.	ACP/EEMP	3
61. May 29, 1969	Diagrams of sampling and analytical systems—proposed.	EEMP	4
62. June 5, 1969	Effective and economic control of auto emissions—Sarto.	EVMP	7
63. July 1, 1969	Preliminary evaluation of NO_x analyzer—Jackson	General Motors	3
64. July 1, 1969	Determination of CO_2 at Wahnsdorf, Germany—published.	Mercedes-Benz	2
65. July 1, 1969	Comparison of 3 dynamometers in Germany	do	4
66. July 1, 1969	Dynamometer effects on emissions using CVS	Nissan	2
67. July 23, 1969	Foreign cycle evaluation—Lombardi	EEMP	2

HEAVY VEHICLE PANEL REPORTS

1. Mar. 7, 1969	Evaluation control procedures for heavy trucks	HVP	4
2. Mar. 26, 1969	Reduction of nitrogen oxides in automobile exhaust	Nippon Denso	11
3. May 22, 1969	Outline for research program for heavy vehicle emission data.	HVP	2

AD HOC TRAFFIC SURVEY PANEL REPORTS

1. May 24, 1967	Comparison of Chrysler 50,000 mile and AMA durability scehdules.	Chrysler Corp	4
2. May 24, 1957	Comparison of durability schedules	General Motors Corp	1
3. Mar. 27 1968	Consideration in traffic survey and test cycle development.	General Motors Corp., Chrysler Corp., Fard Motor Co.	3
4. Sept. 30, 1968	Background of vehicle exhaust gas text procedures in Japan.	Toyota Motor Co. Ltd	4
5. Feb. 5, 1969	European driving cycle	Renault	4

ATMOSPHERIC CHEMISTRY PANEL REPORTS

1. Mar. 4, 1969	Nitrogen oxides in the atmosphere	ACP	34
2. July 8, 1969	HEW meeting—Cincinnati reactivity criteria	ACP	6

VEHICLE EMISSION SURVEILLANCE PANEL REPORTS

1. Oct. 11, 1967	1967surveillance program on high mileage exhaust emission equipped vehicles.	Ford Motor Co	23
2. Mar. 27, 1969	Hot versus cold start surveilance testing	VESP	9
3. June, , 1969	Surveillance data summary report to ESC	VESP	5

FUEL SYSTEMS EMISSION PANEL REPORTS

1. Oct. 18, 1967	Letter from AMA to NAPCA outlining available data on evaporative control systems.	AMA-VCP, General Motors	10
2. Oct. 25, 1967	Charcoal canister evaporative emissions control system.	General Motors	9
3. Oct. 25, 1967	Crankcase storage of evaporative emissions	do	10
4. Dec. 1, 1967	Carbon air cleaner evaporative control	Ford	10
5. Dec. 1, 1967	Crankcase storage system—Evaporative control	do	15
6. Dec. 1, 1967	History of evaporative control studies	do	13
7. January 1968	Chrysler closed-vent system	Chrysler	8
8. January 1968	AMC evaporative systems	American Motors	6
9. Apr. 24, 1968	Results of lab cross program	FSEP (charts)	5
10. June 14, 1968	Evaporative loss data	do	7
11. July 1968	Absorption of HC vapor by charcoal	Toyota	15
12. Aug. 23, 1968	Proposed procedure for determination of liquid fuel losses from vehicle fuel tank.	FSEP	9

FUEL SYSTEMS EMISSIONS PANEL REPORTS—Continued

Date of presentation	Subject	Prepared by	Number of pages
13. Sept. 27, 1968	Proposed procedure for determination of liquid fuel from vehicle fuel tank.		8
14. Oct. 15, 1968	Joint (FSEP and HVP) report to ESC on test procedure for heavy truck losses.	FSEP	4
15. Mar. 18, 1969	Preliminary progress report of shred test procedure.	FSEP	3
16. Mar. 24, 1969	Fuel temperature versus vapor temperature	Kaiser Jeep	2
17. Mar. 24, 1969	Comparison of evaporating test procedures	Ford	9
18. Mar. 24, 1969	GM test on effect of heating test on evaporator emission.	General Motors	2
19. Mar. 25, 1969	Deterioration factor of evaporator emission data	Toyota	7
20. Mar. 8, 1969	Comparative shed tests	General Motors (charts)	2
21. Apr. 18, 1969	Report of evaporator testing	Ford, General Motors, Chrysler, American Motors.	7
22. Apr. 23, 1969	Effect of heating method of fuel tank on evaporator emission.	Nissan	4
23. Apr. 23, 1969	Heating pad installation versus fuel tank emissions	Kaiser Jeep	3
24. Apr. 28, 1969	Review of shed testing data	Ford, American Motors, Chrysler.	6
25. May 5, 1969	Fuel tank heating methods	FSEP	23
26. May 6, 1969	Laboratory cross check program	FSEP	11
27. May 18, 1969	Shed test on control equipped cars	General Motors	2
28. July 1, 1969	Comparison of evaporation test sequences	FSEP	6
29. July 18, 1969	Proposals for engineering acceptance of evaporation control systems.	FSEP	3

SEPTEMBER 15, 1969.

Hon. RICHARD W. MCLAREN,
Assistant Attorney General, Antitrust Division, Department of Justice, Washington, D.C.

DEAR MR. MCLAREN: I have your letter of September 11, 1969 indicating that the Antitrust Division preferred to propose a consent decree with the four major auto manufacturers and the Automobile Manufacturers Association (AMA) instead of proceeding to full trial. The Department's press release, but not the full text of the consent decree proposal, was enclosed. There is a significant difference between the two—the press release was an optimistic gloss that could and did mislead the press into reporting that the Division had obtained a victory for the people in achieving a stipulation from the domestic auto industry that they will obey the antitrust laws in the future in return for the Division's forgetting the past and keeping past records about the industry's conspiracy confidential.

What the domestic auto companies conspired over a period of at least 16 years to do—restrain the development and marketing of auto exhaust control systems—is a crime under the Sherman Act. Collusive, anti-competitive agreements which result in seriously jeopardizing the capacity of citizens to breathe air without carcinogenic and other lethal and violent pollutants would, under the most normal of expectations, be prosecuted by the Division as a crime. That course of enforcement was indeed initiated by your predecessors, Donald Turner and Edward Zimmerman in mid-1968. Grand Jury proceedings for 18 months resulted in the Division's trial attorney's request to Mr. Turner for permission to ask the Grand Jury to return an indictment. The Grand Jury was even willing to return an indictment regardless of what instructions were forwarded from Washington—so convinced was it of the criminality of the behavior detailed during these 18 months. Mr. Turner dropped the criminal case, without any public explanation, and had the Grand Jury discharged. One year later, in January 1969, a civil complaint was filed. Nine months after that, the civil complaint was in effect dropped in favor of a porous, proposed consent decree, stripped to the minimum of what the legitimate impact of the law should have been.

Is this where five years of Antitrust Division involvement and expenditure of numerous man-years is to end? I should like to detail some reasons why the answer to this question must be "no."

Over the years, a large proportion of the civil actions brought by the Antitrust Division have been terminated by consent decrees. The criteria employed have rarely been made clear. However, it is known that scarce manpower and judicial delay are important factors. Year after year, those who have lead and supervised the Antitrust Division have undermined or weakened antitrust enforcement by

simply referring to those two conditions. At the same time, there has been no sustained effort to obtain more funds for the Division or to develop procedures (with the exception of the CID development earlier in this decade) which will accelerate any judicial recourse or at least improve the bargaining power of the government that more expenditious trial reflects.

It seems to be relevant to suggest a number of questions which should be asked in the automobile smog case before a consent judgment is considered or approved:

1. Are there important and unresolved issues of law which merit judicial determination?

2. Are there important rights of public and private institutions and citizens which can be eroded or erased by a consent judgment as proposed?

3. Does the seriousness of the antitrust violation in this case argue for the greater deterrent and public educational purposes achieved by a civil trial or the resumption of the Division's criminal action?

4. Does the proposed consent decree achieve the announced objective of Attorney General John M. Mitchell who described it last week as representing "strong federal action to encourage widespread competitive research and marketing of more effective auto anti-pollution devices?"

Matters of fact and law point to clearly affirmative responses to questions (1) (2) & (3) and a negative response to question (4).

The present case offers an excellent opportunity for the Antitrust Division to establish judicially two important principles which would have enormous replicative value over the behavior of modern industry striving to restrain the rate of innovation to the detriment of competition and human welfare. As you know, the Department's complaint of January 10, 1[illegible] requested that the defendants be restrained from making joint responses to government regulatory agencies concerned with air pollution control. For years the Automobile Manufacturers Association has been the instrument of precise collusion by the auto companies to develop common positions on questions of pollution and safety and to head off or suppress any potential diversity of response. Even after the Department commenced its investigation into this conspiracy, the AMA was developing and using a stock speech on air pollution—a speech which was given, for example, both by Dr. Fred W. Bowditch, Chief Engineer for General Motors and Mr. Donald A. Jensen. Ford's executive engineer in charge of vehicle emissions. Collusive trade association activity continues to be a prime anti-competitive practice in this country. Such activity is long overdue for authoritative judicial resolution and the emergence of judge-made law that would give pause to other trade associations which exert similar, if not greater control, over their members and enforce the domimant firm(s)' policy over smaller industry firms. The proposed consent decree loses this opportunity.

The second principle requiring case law development relates to "product fixing." The automobile industry has restrained competition among manufacturers in the area of product quality. The consumer movement can produce numerous instances of such lowest common denominator quality throughout an industry. The auto companies activities in the motor vehicle emissions field are in-this sense symptomatic of a disease which affects wide areas of the economy. By not moving against this sort of collusion, the Division has relinquished an opportunity to formulate a crucial, new precedent that is rooted in old antitrust doctrine. The instant case is ripe for this determination and the Division has the benefit of five years of investigation as well.

Because the antitrust laws recognize the rights of persons or groups to initiate private antitrust actions, the Division is in a trusteeship position thereto. Any decision made must take into some account how the final resolution will affect the rights of private and public parties under the antiturst laws. In this case, municipal and other public bodies have displayed a strong interest in antitrust enfocrement vs. the auto conspiracy as well as recovering in separate actions damages which they have incurred as a result of auto pollution. The possibility that local governmental bodies, business firms and individual citizens may wish to adjudicate their rights is severely limited by the proposed consent decree. As you know, Section 5 of the Clayton Act provides that consent judgments, unlike other final judgments in cases brought by the United States, shall not be considered prima facie evidence against the defendant in a treble-damage suit. The practical effect of this provision is that potential treble-damage plaintiffs would have to duplicate the investigative process which took the Department several

years and several hundreds of thousands of dollars even with its extraordinary discovery powers. Los Angeles County already has filed a one hundred million dollar suit against the automobile manufacturers, seeking to recoup some of the loss to the County resulting from this corporate conspiracy to hold back on pollution controls. Further, the California Attorney General, acting on behalf of the State, has been denied access to the Justice Department's information about the auto pollution case. The evidence of the conspiracy exists in the Justice Department's possession and the Department seems determined not to have any of it surface in a public trial. In a critical treatment of the Department's consent degree program ten years ago, the House Antitrust Subcommittee described precisely this effect:

The almost inevitable consequence of the acceptance of a consent decree by the Department of Justice . . . is to deprive suitors, who have been injured by the unlawful conduct, of their statutory remedies under the antitrust laws."

The Department's complaint charges the auto industry with collusive behavior having devastating consequences for the peoples' health in this country. At least 50% of the nation's air pollution comes from the motor vehicles' internal combustion engines. Medical and other epidemiological studies have linked these pollutants with diseases ranging from cancer to emphysema. Property damage from corrosive pollutants is estimated at $13 billion annually by federal officials. Half of this amount is a very substantial cost inflicted on this nation by the auto industry's intransigent refusal to innovate over the past generation. Can anyone deny the need and benefit for the public to learn about the nature and depth of this colossal corporate crime? The citizens of this country, who are the customers of this industry, have a right to know the extent to which the auto companies are deliberately responsible for the enormous health, economic and aesthetic damages caused by the internal combustion engine. One of the purposes of a public trial is deterrence; the Division has chosen to lose a grand opportunity to bring these companies and their harmful practices into the public arena of a courtroom. This aspect of the Division's case alone would have a greater deterrent effect than the tightest of consent judgments. Since it is not any longer the practice of antitrust enforcement to pierce the corporate veil and hold the culpable officials responsible, a public trial would at the least have shown that such corporate officials are holding far greater power over citizens in this country than they can exercise responsibly or even legally.

What of the proposed consent decree? The proposal can hardly be stronger than the complaint which itself is the result of a process of enforcement erosion which began with an intended cirminal prosecution and ended with a meek request for injunctive relief. The complaint did not even contain a request for the imposition of civil damages pursuant to the antitrust laws. (Like the drug cases, the federal government has incurred damage to its property and personnel from this conspiracy.) The process of secret, ex parte type negotiations with representatives of corporate defendants, in particular Lloyd N. Cutler, counsel for the AMA, discourages confidence in antitrust enforcement and facilitates sloppy or political decision-making. When decisions can be made without prior citizen access or without criteria publicly displayed on which such decisions are rendered or without adequate explanation, abuses, distortions and lacerations of the public interest can occur with greater frequency than would be the case otherwise.

The following weaknesses can be cited in the proposed consent decree:

1. There is no provision requiring the keeping of records by the defendants. For example, the Department has no assurance that minutes or transcripts will be kept of AMA committee meetings on pollution matters or that there will be records kept of informal discussions between executives and representatives of various auto companies. A section of the proposed decree requires written reports concerning any matters contained in the decree, but only "upon the written request of the Attorney General or the Assistant Attorney General in charge of the Antitrust Division. . . ." If the Department is serious about its surveillance responsibilities over the consent judgment, why doesn't the proposed decree place an affirmative responsibility on the companies to make periodic reports concerning the matters covered by the decree? Why, for instance, are not the companies required to report the terms of all licenses granted and purchased? Why are there no reports on the status of research relating to motor vehicle emissions?

The task of surveillance, effective surveillance, is so formidable that it raises a question whether the Division is even less equipped to monitor compliance with the decree than it is to engage in complicated litigation which would permit

other parties to have the information on which to base their vigilance against antitrust violations by the auto industry. Certainly the terms of the decree proposed last week do not facilitate surveillance. Neither does the fact that the Divisions Judgement Section is composed of only 12 professional personnel with no more than half that number having the burden of trying to see that the many hundreds of consent decrees are being complied with. Judged on any basis—cost benefit, importance of the case etc., the resources which the Division can devote to litigation are greater than those devoted to compliance.

2. Section VI(A)(3) of the proposed decree requires defendant AMA to make available for copying or for examination by any person the technical reports in its possession or control prepared or exchanged by defendants pursuant to said cross-license within two years perior to the entry of this Final Judgment. Why only two years when the Department alleges the conspiracy to have begun at least in 1953 and when the Department alleges specific conspiracies to delay installations in 1961, 1962-3 and 1964. There is also the onerous additional proviso that any person who requests such information agrees to offer each signatoroy party to the AMA cross-licensing agreement of July 1, 1955, as amended, and any subsidiary thereof, nonexclusive license rights with respect to any patents or patent applications based upon information obtained from AMA or its members who are defendants in this case. This proviso can vitiate the purpose of the aforementioned section VI(A)(3) since it requires firms or individuals to become entangled in a serious risk of harassing litigation where the richest firm wins. What small firm is going to take the risk? Consequently, the purpose of this section to encourage proliferation of information collusively obtained or possessed so as to promote competition fails.

3. Two provisions which the Department emphasized in its September 11, 1969 press release were the restraint against exchanging confidential information (IV A 2 a) and the restraint against filing joint statements (IV A 2 g) to regulatory agencies or matters pertaining to pollution or automotive safety are scheduled to expire quietly in ten years under Section IX of the proposed decree unless the Department applies for a continuation after nine years. Why, if these two practices are considered anticompetitive—and indeed they go to the base of the conspiracy—will they be any less anticompetitive in ten years?

In the case of the proposed restraint on joint statements, the qualifications make the restraint mere paper in impact. These exemptions to the ban on joint statements via the AMA are: statements relating to (1) the authority of the agency involving; (2) the draftsmanship of or the scientific need for standards or regulations; (3) test procedures or test data relevant to standards or regulations; or (4) the general engineering requirements of standards or regulations based upon publicly available information. In addition, the proposed decree (IV (A) (1)(g)) permits joint filing on the critical point of ability to comply with a particular standard or regulation if there is a written agency authorization for such a joint statement. What kind of naivete or incompetence does this draftsmanship reveal on the part of the public's representatives in your Division? Mr. Cutler has probably drafted a form request to the various agencies on behalf of the AMA to take advantage of just that blatant loophole, and will approach the agencies at the appropriate time.

4. There is no provision for requesting the Court to release the Grand Jury transcript and other documents in order that third parties have the opportunity to adjudicate their rights. Even in the case of U.S. vs. Harper and Row et al (the book conspiracy case), the Division had a information release provision. There is also no ban on the destruction of corporate or AMA documents re the conspiracy since 1953.

In the light of the fore-going and other arguments made to your staff by concerned public representatives, I urge you to withdraw your consent to this proposed decree, as provided for on page 1 of the stipulation, and reconsider the necessity to initiate criminal action against the defendants or at the least a civil action with broader relief than requested by the January 10, 1969 complaint. In the most unsatisfactory alternative, the proposed decree should be amended to take into account and eliminate the afore-mentioned deficiencies and to incorporate a strong information disclosure provision so that third parties. such as Los Angeles County, can do the job that your Division failed to do. Better a trial sought and lost than a consent decree gained in the form of a legal fiction and propped up by a compliance capability that is beyond pathos.

During your reconsideration, if you so undertake one, may I suggest that you take note of the following commentary on the infirmity of the consent decree and its continuing ludicrous-tragic infrastructure:

"When a corporate official knows that the probabilities are that, if his activities are detected, antitrust attack on a proposed economic program can be concluded amicably, with no notoriety, and with little danger of resultant private antitrust actions, there is virtually nothing to lose and everything to gain from undertaking a questionable program. Large scale use of the consent decree to conclude antitrust suits instituted by the United States, therefore, amounts to an invitation to corporate officers to undertake activities which may violate the law." (1959 House Antitrust Subcommittee Report)

In conclusion, I should like to ask the following questions:

1. What allocation of compliance manpower do you envision necessary for even the minimal provisions of the proposed consent decree? What compliance program has been developed?

2. The reason given, among others, for resorting to the consent decree resolution was the protracted delay in the courts and the manpower drain. How do you envision responding to this state of affairs—by relying more heavily on consent decrees as your case load builds up or by constructing the case for doubling or quadrupling your staff and resources if the remnants of the competitive enterprise system are to be preserved and taking that case to the Congress and to the public? As you realize every day, the Antitrust Division's budget, in real terms, has not increased over the past six years—once pay increases etc. are accounted. This year, the entire budget for the Antitrust Division permits a manpower base of about 170 practicing attorneys (about the size of the largest private law firms) and in dollar terms is equivalent to approximately 3 hours gross revenue (on a 24 hour basis year around) of General Motors. Is it not time to unveil the farce of antitrust enforcement and proceed to substance?

3. Do you intend to set forth your philosophy on consent decree uses and procedures in the near future? Do you believe that the public should have access, in terms of input and commentary on Departmental proposals, *before* the consent decree agreement is announced. A few years ago, the Department adopted the 30 day rule to give interested parties time to file their objections; but this is late for many interested parties and by this time the Department has made up its mind. What is necessary is to give the public at least a partial access to persuade the Department instead of the present secret negotiations between the Department and the defendants.

4. Your predecessor, Donald Turner, looked dimly on private antitrust efforts as unduly disruptive of the Department's public policy on antitrust. Do you share this reservation? Do you think the proposed consent decree is adequate to permit third parties to adjudicate their rights?

5. Do you not concede the likelihood of anticompetitive effects flowing from grantback provisions (such as in IVB2b) which run counter to the announced thrust of the consent decree proposal?

By including the comments of Dr. Lee A. DuBridge, President Nixon's science advisor, and the approval of the Department of Health, Education and Welfare, in your September 11, 1969 press release, you recognize the broad policy significance of this auto smog antitrust case and the proposed consent decree. Others in Congress and in local governments agree. There is every indication that this is going to be the most widely contested decree in antitrust history. In order to have the opportunity for timely intervention, within the 30 day limit, I would appreciate receiving your responses on the aforenoted requests for more stringent legal action against the auto industry and, alternatively, for stricter relief in the consent decree.

Thank you for your consideration of the above suggestions.

Sincerely yours,

RALPH NADER.

LOS ANGELES COUNTY INTERVENES IN SMOG CASE

(By Hon. George E. Brown, Jr.)

Mr. BROWN of California. Mr. Speaker, last week the Los Angeles County Board of Supervisors acted to intervene as a plaintiff in the antitrust case pending against automobile manufacturers accused of conspiracy to limit development of effective air pollution controls.

The complaint and the notice of motion include some vital analysis relevant to the issue of allowing a consent decree in this case, and I now place them in the RECORD at this point, along with a relevant motion adopted this week by the board of supervisors:

[U.S. District Court, Central District of California]

UNITED STATES OF AMERICA, PLAINTIFF, v. AUTOMOBILE MANUFACTURERS ASSOCIATION, INC.; GENERAL MOTORS CORP.; FORD MOTOR CO.; CHRYSLER CORP.; AND AMERICAN MOTORS CORP., DEFENDANTS

(Civil No. 69-75-JWC; filed 1/10/69; complaint in intervention of county of Los Angeles (State of California) and Air Pollution Control District of the County of Los Angeles (State of California)

COMPLAINT

Come now the County of Los Angeles, of the State of California, and the Air Pollution Control District of the County of Los Angeles (State of California), and for cause of action against the Defendants Automobile Manufacturers Association, Inc.; General Motors Corporation; Ford Motor Company; Chrysler Corporation; and American Motors Corporation allege as follows:

I

That Plaintiff in Intervention County of Los Angeles (County) is a public corporation and a political subdivision of the State of California.

II

That Plaintiff in Intervention Air Pollution Control District of the County of Los Angeles (APCD) is a public agency formed and existing pursuant to the laws of the State of California.

III

That the Air Pollution Control District (APCD) is charged by the laws of the State of California with the duty of protecting the health and welfare of the people of Los Angeles County from the effects of air contamination; that since its creation in 1947 the APCD has expended approximately sixty millions of dollars ($60,000,000.00) of public funds in attempting to reduce air pollution, in Los Angeles County; that the source of said funds is the Treasury of the County of Los Angeles.

IV

That at all times alleged in the Complaint the County of Los Angeles was charged by law with the duty of providing medical services and other health services to more than one-half million people who are and were residents of the County and are and were unable to pay for such services.

V

That each year since 1952 the County of Los Angeles has purchased more than 500 motor vehicles from the named Defendants; that as a proximate result of the conspiracy alleged in the Complaint the motor vehicles purchased by them were not equipped with efficient air-pollution control devices, and that between 1952 and 1961 said vehicles were not equipped with any such devices whatsoever.

VI

That as a proximate result of the offenses alleged in the Complaint the Defendants have caused to be emitted into the air of Los Angeles County air contaminants in the form of hydrocarbons, carbon monoxide, oxides of nitrogen, particulate matter, and other air contaminants; that the amount of such emissions varies and has varied from day to day and that the average amount of such air contaminants emitted in Los Angeles County presently exceeds 12,000 tons per day.

VI

That as a proximate result of said emissions of air contamination the County of Los Angeles has been forced to expend many millions of dollars in providing medical care and other health services to residents of Los Angeles County; that said emissions of air contamination have caused respiratory diseases and aggravate and have aggravated respiratory diseases of residents of Los Angeles

County; and that many thousands of persons suffering from respiratory diseases were treated by County hospitals and other facilities, all at the expense of the County, during each year since 1952.

VII

That the interests of these Plaintiffs will not be adequately protected by the present Parties to the proceeding.

Wherefore, the Plaintiffs in Intervention pray:

1. That the Court permit the Plaintiffs in Intervention to become parties to this action on the side of the Plaintiff and that they be permitted to take part in all proceedings in this action.

2. That the Court adjudge and decree that the Defendants have engaged in a combination and conspiracy, in unreasonable restraint of the aforesaid interstate trade and commerce, in violation of Section 1 of the Sherman Act.

3. That each of the Defendants named in this Complaint, its successors, assignees and transferees, and the respective officers, directors, agents, and employees thereof, and all persons acting or claiming to act on behalf thereof:

(a) be enjoined from continuing, maintaining, or renewing, directly or indirectly, the combination or conspiracy hereinbefore alleged, or from engaging in any other practice, plan, program, or device having a similar effect;

(b) be enjoined from entering into any agreements, arrangements, understandings, plan or program with any other person, partnership, or corporation, directly or indirectly:

(1) to delay installation of air pollution control equipment or otherwise restrain individual decisions as to installation dates;

(2) to restrict individual publicity of research and development relating to air pollution control technology;

(3) to require joint assessment of the value of patents or patent rights relating to air pollution control equipment;

(4) to require that acquisition of patent rights relating to air pollution technology be conditioned upon availability of such rights to others upon a most-favored-purchaser basis; or

(5) to respond jointly to requests by government regulatory agencies for information or proposals concerning air pollution control technology unless such agency requests a joint response in a particular case; and

(c) be required to issue to any applicant interested in developing motor vehicle air pollution technology unrestricted, royalty-free licenses and production know-how under all United States patents owned, controlled, or applied for to which the cross-licensing agreement dated July 1, 1955, as amended, has been applicable, and to make available to any such applicant all other know-how related to air pollution control technology which has been exchanged with any other defendant.

4. That the Plaintiff have such other, further, and different relief as the nature of the case may require and the Court may deem just and proper in the premises, including cancellation of the cross-licensing agreement dated July 1, 1955, as amended, and an injunction ensuring that all future joint arrangements relating to air pollution control technology be appropriately limited as to subject matter of joint effort and numbers of participants so as to maintain competition in the development of air pollution technology.

5. That these Plaintiffs be awarded damages against the Defendants, and each of them, in the sum of One Hundred Million Dollars ($100,000,000.00).

6. That the Plaintiffs in Intervention recover their costs of suit herein and receive such other and additional relief as is just in the premises.

Dated: September 5, 1969.

JOHN D. MAHARG,
County Counsel.
By DAVID D. MIX,
Assistant County Counsel,
Attorneys for Plaintiffs in Intervention.

CERTIFICATE OF SERVICE BY MAIL

I hereby certify; under penalty of perjury, that I am and at all times herein mentioned have been a citizen of the United States and a resident of the County of Los Angeles, over the age of eighteen years and not a party to nor interested in the within action; that my business address is 648 Hall of Administration, City of Los Angeles, County of Los Angeles, State of California;

That on the 5th day of September, 1969, I served the attached Notice of Motion and Motion to Intervene with accompanying documents upon attorneys of record

for United States of America; Automobile Manufacturers Association, Inc.; General Motors Corporation; Ford Motor Company; Chrysler Corporation; and American Motors Corporation by depositing a copy thereof, enclosed in a sealed envelope with postage thereon fully prepaid, in a United States mail box in Los Angeles, California, addressed as follows:

Raymond W. Phillips, Dept. of Justice, Antitrust Division, 1307 U.S. Court House, 312 North Spring St., Los Angeles, California 90012. [Attorneys for Plaintiff, United States of America].

Gibson, Dunn & Crutcher, Julian O. von Kalinowski, Paul G. Bower, Robert E. Cooper, 634 South Spring Street, Los Angeles, California 90014. [Attorneys for Defendant, Automobile Manufacturers Association, Inc.]

Overton, Lyman & Prince, Carl J. Schuck, 550 S. Flower St., Suite 607, Los Angeles, Calif. 90017 [Attorneys for Defendant, Ford Motor Company].

Lawler, Felix & Hall, Marcus Mattson, Robert Henigson, 605 W. Olympic Blvd., Suite 80, Los Angeles, Calif. 90015 [Attorneys for Defendant, General Motors Corporation].

McCutchen, Black, Verleger & Shea, Philip K. Verleger, William G. Shea, 615 S. Flower St., Suite 1111, Los Angeles, Calif. 90017 [Attorneys for Defendant, Chrysler Corporation].

O'Melveny & Myers, Allyn O. Kreps, Girard E. Boudreau, 611 West 6th Street, Los Angeles, Calif. 90017 [Attorneys for Defendant, American Motors Corporation].

and that the persons on whom said service was made have their offices at a place where there is a delivery service by United States mail, and that there is a regular communication by mail between the place of mailing and the place so addressed.

Dated: September 5, 1969.

BONITA M. AUER.

[U.S. District Court, Central District of California]

UNITED STATES OF AMERICA, PLAINTIFF, v. AUTOMOBILE MANUFACTURERS ASSOCIATION, INC.; GENERAL MOTORS CORP.; FORD MOTOR CO.; CHRYSLER CORP.; AND AMERICAN MOTORS CORP., DEFENDANTS

(Civil No. 69-75-JWC, notice of motion and motion to intervene as plaintiffs)

To the following:

Raymond W. Phillips, Department of Justice, Antitrust Division, 1307 U.S. Court House, 312 North Spring Street, Los Angeles, California 90012 [Respectively, attorney for Plaintiff, United States of America].

Gibson, Dunn & Crutcher, Julian O. von Kalinowski, Paul G. Bower, Robert E. Cooper, 634 South Spring Street, Los Angeles, California 90014 [Respectively, attorneys for Defendant, Automobile Manufacturers Association, Inc.].

Overton, Lyman & Prince, Carl J. Schuck, 550 South Flower Street, Suite 607, Los Angeles, California 90017 [Respectively, attorneys for Defendant, Ford Motor Company].

Lawler, Felix & Hall, Marcus Mattson, Robert Henigson, 605 West Olympic Boulevard, Suite 800, Los Angeles, California 90015 [Respectively, attorneys for Defendant, General Motors Corporation].

McCutchen, Black, Verleger & Shea, Philip K. Verleger, William G. Shea, 615 Cooper, 634 South Spring Street, Los Angeles, Calofirnia 90014 [Respectively, attorneys for Defendant, Chrysler Corporation].

O'Melvey & Myers, Allyn O. Kreps, Girard E. Boudreau, 611 West 6th Street, Los Angeles, California 90017 [Respectively, attorneys for Defendant, American Motors Corporation].

Please be advised that on October 6, 1969, at the hour of 10:00 A.M. or as soon thereafter as counsel may be heard, the undersigned, County of Los Angeles (State of California) and the Air Pollution Control District of the County of Los Angeles (State of California) will make formal motion in Courtroom 10, United States Court House, 312 North Spring Street, Los Angeles, California, to intervene in the above-referenced action.

The County of Los Angeles and the Air Pollution Control District of the County of Los Angeles move pursuant to Rule 24(a)(2) and Rule 24(b)(2) of the Federal Rules of Civil Procedure, for leave to intervene as plaintiffs in the above-entitled action to assert the claims set forth in the proposed Complaint, a copy of which is attached, on the following grounds:

1. The claims of the County of Los Angeles and the Air Pollution Control District of the County of Los Angeles contained in the proposed Complaint for Intervention and the claims of the United States of America in the main action have substantial questions of law and fact in common. The common questions of law and fact are whether the Defendants engaged in a combination or conspiracy to prevent the development and distribution of motor vehicle air pollution control equipment. The interests of the Intervenors in these common questions of law and fact, however are different and distinct from the interests of the Plaintiff, the United States of America. The Plaintiff is concerned about the direct and immediate results of the common questions of law and fact on free competition and interstate commerce. Intervenors' interests, on the other hand, are the direct and immediate result of the common questions of law and fact on the health and economic vitality of the residents of the County of Los Angeles. The Plaintiff is not adequately representing the interests of the Intervenors.

The Intervenors must become a party to the main action so that when the common questions of law and fact are resolved, the interests of the Intervenors will be protected by:

(a) Enjoining the combination and conspiracy so that pollution-free motor vehicles are developed to avoid the diversion of public funds for the purchase of ineffective motor vehicle air pollution control equipment by the Intervenors as public end users.

(b) Enjoining the combination and conspiracy so that effective motor vehicle air pollution control equipment may be developed at a lesser price and thereby avoid the further diversion of public funds for only partially effective motor vehicle air pollution control equipment.

(c) Enjoining the combination and conspiracy which causes ineffective motor vehicle air pollution control equipment to be marketed and thereby causes substantial diversion of public funds for medical services made necessary by the damaging consequences of breathing polluted air by residents of Los Angeles County.

2. Unless these Plaintiffs are permitted to intervene the United States and the Defendants may settle this matter by stipulation or otherwise. In such an event, the facts of the conspiracy will be forever lost to these moving parties and to all persons who have been damaged by said conspiracy.

Because of the above-enumerated interests in the common questions of law and fact (preventing the development and distribution of effective motor vehicle air pollution control equipment), the interests of Plaintiffs in Intervention are separate and distinct from the interests of the United States of America, and said Plaintiff cannot alone adequately represent theinterests of the Intervenors.

3. To grant the Motion to Intervene will not unduly delay or prejudice the rights of the original parties. The Plaintiff can continue to focus on the competition and interstate commerce implications of the combination and conspiracy. The Defendants can continue to focus on the common questions of law and fact—a combination and conspiracy to prevent the development and distribution of motor vehicle air pollution control equipment. No delay will be caused by intervention. Only prejudice will result if the Motion to Intervene is denied.

JOHN D. MAHARG,
County Counsel.
By DAVID D. MIX,
Assistant County Counsel.

Attorneys for the County of Los Angeles and Air Pollution Control District, County of Los Angeles.

[U.S.District Court, Central District of California]

UNITED STATES OF AMERICA, PLAINTIFF *v.* AUTOMOTIVE MANUFACTURERS ASSOCIATION, INC.: GENERAL MOTORS CORP.; FORD MOTOR CO.; CHRYSLER CORP.; AND AMERICAN MOTORS CORP., DEFENDANTS

(Civil No. 69–75 JWC memorandum in support of complaint in intervention of County of Los Angeles and air pollution control district)

I

Rule 24, Federal Rules of Civil Procedure, is to be broadly construed.

Rule 24(a)(2) of the Federal Rules of Civil Procedure provides for intervention of rights as follows:

"Upon timely application anyone sholl be permitted to intervene in an action . . . (2) when the applicant claims an interest relating to the property or transaction which is the subject of the action and he is so situated that the disposition of the action may, as a practical matter, impair or impede, his ability to protect that interest, unless the applicant's interest is adequately represented by existing parties."

Rule 24 was amended to its present form in 1966. According to the United States Supreme Court, the purpose of the revision was intended to inject elasticity into the rule and to eliminate the restrictive approach of the older, more rigid cases interpreting the rule. *Cascade Nat. Gas* v. *El Paso Nat. Gas*, 386 U.S. 129. Recent cases have applied a very broad interpretation to Rule 24(a)(2). *Cascade Nat. Gas, supra*, at pages 135-6; *Hopsen* v. *Hanson*, 44 F.R.D. 18 (D.D.C. 1968); *Nuesse* v. *Camp*. 385 F. 2d 694 (DC CIR. 1967).

An absolute right exists, as in this case, when the Plaintiff in Intervention claims an interest relating to the property or transaction which is not adequately represented by existing parties. A reading of Plaintiff in Intervention's complaint reveals that the Plaintiff shares an identical interest with the United States in the transaction which is the subject of the lawsuit. *Credits Commutation Co.* v. *U.S.*, 177 U.S. 311, 315-316; *Minot* v. *Mastin* (C.A.A. 8th 1899) 95 F. 734, 739. In view of the identity of interest it is essential that the Plaintiff be entitled to intervene in order to protect such interest.

In addition to intervention as of right, Plaintiff in Intervention is entitled to permissively intervene pursuant to Federal Rule 24(b) which provides in part as follows:

"Upon timely application anyone may be permitted to intervene in an action . . . (2) when an applicant's claim or defense in the main action is a question of law or fact in common."

There is no question Plaintiff in Intervention has several questions of law and fact in common with the United States relative to the pending action. *Brinkerhoff* v. *Holland Trust Co.* (CCSDNY) 159 F. 911; *United States* v. *Utica, Chen. & Susquehanna Valley Ry. Co.*, 48 F. Supp. 903; *Central Louisiana Elec. Co.* v. *Rural Electrification Administration* (W.D.La. 1964) 236 F. Supp. 271.

II

United States Code, title 15, section 5, vests the court with authority to join parties to a pending action.

United States Code, Title 15, Sec. 5, thereof provides as follows:

"Whenever it shall appear to the court before which any proceeding under section 4 of this title may be pending, that the ends of justice require that other parties should be brought before the court, the court may cause them to be summoned, whether they reside in the district in which the court is held or not; and subpoenas to that end may be served in any district by the marshal thereof."

Plaintiff in Intervention alleges an interest in the vast assemblage of proposed evidence which the United States will use in its case against the parties defendant but which the United States refuses to divulge to the Plaintiff in Intervention. Pursuant to the authority vested by Title 15, Section 5, the court may bring in additional parties to any suit brought by the United States. As a practical matter, Plaintiff alleges that pursuant to this section the Court should exercise its authority to dispose of all claims arising out of the transaction against the parties defendant in one litigation. *State of Georgia* v. *Pennsylvania Ry. Co.*, 655 Ct. 716.

Respectfully submitted,

JOHN D. MAHARG,
County Counsel.
By DAVID D. MIX,
Assistant County Counsel.

CERTIFICATE OF SERVICE BY MAIL

I hereby certify, under penalty of perjury, that I am and at all times herein mentioned have been a citizen of the United States and a resident of the County of Los Angeles, over the age of eighteen years and not a party to nor interested in the within action; that my business address is 648 Hall of Administration, City of Los Angeles, County of Los Angeles, State of California;

That on the 5th day of September, 1969, I served the attached Notice of Motion and Motion to Intervene with accompanying documents upon attorneys of record

for United States of America; Automobile Manufacturers Association, Inc.; General Motors Corporation; Ford Motor Company; Chrysler Corporation; and American Motors Corporation, by depositing a copy thereof, enclosed in a sealed envelope with postage thereon fully prepaid, in a United States mail box in Los Angeles, California, addressed as follows:

Raymond W. Philipps, Dept. of Justice, Antitrust Division, 1307 U.S. Court House, 312 North Spring St., Los Angeles, California 90012 [Attorneys for Plaintiff, United States of America].

Gibson, Dunn & Crutcher, Julian O. von Kalinowski, Paul G. Bower, Robert E. Cooper, 634 South Spring Street, Los Angeles, California 90014 [Attorneys for Defendant, Automobile Manufacturers Association, Inc.].

Overton, Lyman & Prince, Carl J. Schuck, 550 S. Flower St., Suite 607, Los Angeles, Calif. 90017 [Attorneys for Defendant, Ford Motor Company].

Lawler, Felix & Hall, Marcus Mattson, Robert Heningson, 605 W. Olympic Blvd., Suite 800, Los Angeles, Calif. 90015 [Attorneys for Defendant, General Motors Corporation].

McCutchen, Black, Verleger & Shea, Philip K. Verleger, William G. Shea, 615 S. Flower St., Suite 1111, Los Angeles, Calif. 90017 [Attorneys for Defendant, Chrysler Corporation].

O'Melvny & Myers, Allyn O. Kreps, Girard E. Boudreau, 611 West 6th Street, Los Angeles, Calif. 90017 [Attorneys for Defendant, American Motors Corporation].

and that the persons on whom said service was made have their offices at a place where there is a delivery service by United States mail, and that there is a regular communication by mail between the place of mailing and the place so addressed.

Dated: September 5, 1969.

BONITA M. AUER.

RESOLUTION OF BOARD OF SUPERVISORS, COUNTY OF LOS ANGELES

On motion of Supervisor Hahn, uninimously carried (Supervisor Debs being temporarily absent), it is ordered that the following resolution be and it is hereby adopted:

"Whereas, citizens of smog-infested areas throughout the United States were shocked when United States Assistant Attorney General Richard W. McClaren announced September 11, 1969 the Department of Justice wants to settle its suit based on secret testimony before a Federal Grand Jury that the automobile manufacturers violated the Sherman Antitrust Act by conspiring to restrain and delay the development and installation of anti-smog devices; and

"Whereas, the County of Los Angeles petitioned the Federal court, requesting to intervene in the suit against the automobile manufacturers and asking $100.-000,000 damages for injuries to the public health and for the cost of the Air Pollution Control District; and

"Whereas, equal justice under the law means that every person as well as the largest corporations shall have the law equally applied, and by having this far-reaching case settled out of court, the General Motors Corporation, Chrysler Corporation, Ford Motor Company and the American Motors Corporation receive favored treatment; and

"Whereas, the public interest would be best served by having an open trial rather than a consent judgment and thereby achieve permanent and satisfactory relief rather than no relief which could follow a consent judgment:

"Now, therefore, be it resolved that the Board of Supervisors of the County of Los Angeles hereby respectfully requests President Richard M. Nixon to direct the Attorney General to reverse the decision made by his subordinate to settle the case, and to direct that a full and open trial proceed as soon as possible in Federal court;

"Be it further resolved that the Senate and the House of Representatives be requested to hold hearings in their appropriate committees on the full aspects of the Federal Grand Jury findings to learn if the public is being fully protected and if action to settle the suit out of court is in the best interest of the citizens of the United Staes;

"Be it further resolved that the Executive Officer send copies of this resolution to all members of the Congress.

"Attest:

"JAMES S. MIZE.

"Executive Officer and Clerk of the Board of Supervisors of the County of Los Angeles."

Mr. BROWN. I note your remark that this authority for research in this area might be better given to the Department of Transportation or the Environmental Protection Agency, your reasoning being that these agencies have superior experience in the handling of Government contracts. I am not sure I understand your logic there. If this research were to be done on a contract basis—and incidentally, it is Senator Tunney's proposal that the Department of Transportation handle this on a grant or contract or insured loan basis—it is still nevertheless true that NASA has not only the in-house research capability but far more experience in the granting of Government contracts over the last 10 years than either of these Government agencies.

Mr. NASH. My comment was intended to mean they had had more experience specifically in the automotive area. We really do not have strong feelings about this as a matter of fact. We simply wanted to raise the issue because it would seem more natural that this authority be vested in either the EPA or the DOT which have primary authority and interest in ground vehicle propulsion systems. I do not have any particular problem with this being done by NASA and it may be that they do have superior contracting ability and would be able to apply a fresh approach to this problem.

Mr. BROWN. Your proposal is not illogical and I am not condemning it on that basis. I think this committee has been seeking to draw a line between a reasonable and a responsible role for NASA and the proper role of a specifically mission-oriented agency.

In general, our feeling is that NASA's role is most appropriate in connection with the overall research and development of new technology. But when it gets to the point where decisions have to be made as to the deployment of a technology that it should go to a mission-oriented agency. I do not know whether we can draw that line in this particular area, but we have, of course, both paths being pursued in the two types of legislation. We would hope that some melding of the two approaches could be properly carried out.

I have no further comments, Mr. Chairman.

Mr. SYMINGTON. I have one question. You referred to the industries inflated quotations on the amounts spent on emission controls and safety. This is something we would like to nail down because I think DOT testified that something like $1 billion plus had been spent by the auto companies in order to comply with the Clean Air Act.

What do you think is the reason for the disparity between your estimates of their investments along these lines and their own testimony? And how would you support your assessment of what they have been doing in that area?

Mr. DITLOW. The data which is used within this testimony and submitted for the record is taken directly from the manufacturer's submission to EPA on their own expenditures for research and development on emission controls.

GENERAL MOTORS CORP., EMISSION CONTROL EXPENDITURES, CALENDAR YEAR BASIS, 1967–76

[In thousands of dollars]

Control system projects	1967	1968	1969	1970	1971	1972	Projected 1973	Projected 1974	Projected 1975	Projected 1976
Catalytic Converters:										
Converter	50	205	243	1,592	4,089	4,775	7,477	7,680	8,161	4,566
Other						4,306	5,166	7,192	7,628	7,502
Questor system						414	1,132	2,593	2,566	2,576
Single catalyst system (combined reduction HC, CO, and NO_x)						11		64	99	49
Crankcase blowby controls (PCV)	1,342	1,530	494	218	492	380	361	377	346	355
Air injector reactor system (AIR)	1,327	1,005	1,016	2,429	3,426	3,913	3,064	3,188	2,981	2,826
Exhaust gas recirculation (EGR)	13	36	230	1,073	3,013	5,495	4,959	4,405	3,802	3,562
Spark control systems (TCS, SCS)	338	611	1,018	3,738	3,469	4,299	3,624	3,504	3,531	3,623
Manifold heat (EFE)	19	32	45		1,570	979	1,284	1,358	1,602	1,917
High energy ignition	463	112	217	1,117	2,695	3,270	3,116	4,161	3,802	3,765
Electric fuel pump						149	171	313	219	231
Exhaust system (long life)						153	146	135	151	144
Fuel filler neck change						131	128	150	105	106
Controlled combustion system (CCS)	1,192	1,210	1,383	2,792	2,811	1,621	1,554	1,056	1,257	1,605
Manifold reactors		111	254	579	516	889	612	670	752	936
Evaporative emission system	563	958	1,057	3,193	2,796	2,179	1,981	1,969	1,831	1,919
Fuel injection	52	459	1,549	3,055	4,128	1,270	336	395	570	520
Asbestos, rubber, etc.						74	47	61	58	65

Gaseous fuels—LPG, LNG, CNG	8		107	176	139	91	110	107	106	108
Fuel specifications	22	95	176	893	2,363	841	747	755	848	920
Smoke, Odor	247	315	466	827	980	1,395	1,556	1,510	1,741	1,823
Carburetion:										
Current models	2,932	2,532	3,030	5,208	7,785	7,846	7,319	8,081	9,475	10,219
Future models	1,797	2,334	2,000	2,068	4,186	11,494	10,518	9,044	7,739	7,682
Emission testing and analysis:										
End of line	533	1,550	2,019	3,318	7,322	9,495	8,908	9,096	9,302	9,952
Other	1,343	1,290	2,177	3,180	[illegible]	8,049	8,269	8,813	9,602	9,955
Alternate power sources	1,641	4,743	8,455	11,333	18,923	20,801	23,685	22,383	22,479	22,202
Other	1,016	1,371	4,370	2,315	[illegible]	4,296	4,090	3,912	4,362	4,724
Subtotal, direct expenditures	14,898	20,499	30,306	49,104	81,581	98,616	100,360	102,972	105,115	103,843
Facilities	17,872	5,108	6,172	23,451	30,471	41,828	112,814	176,956	67,787	33,751
Tools	9,323	1,389	7,749	16,289	25,412	48,165	90,890	167,066	56,481	9,849
Total, direct expenditures including facilities and tools	42,093	26,996	44,227	88,844	137,464	188,609	304,064	446,994	229,383	147,443
Allocated costs	9,053	12,006	19,584	30,132	44,133	48,515	45,936	48,006	50,617	49,557
Total, excluding GM support of MVMA	51,146	39,002	63,811	118,976	181,597	237,124	350,000	495,000	280,000	197,000
GM support of Motor Vehicles Manufacturers Association [1]	101	708	1,230	957	50	740	740	740	740	740
Total expenditures	51,247	39,710	65,041	119,933	181,647	237,864	350,740	495,740	280,740	197,740

[1] Forecast of MVMA support is assumed to be approximately the same as 1972.

Note: The above data display a summary of expenditures for the years 1967 through 1972 and *a projection* through 1976.

GENERAL MOTORS CORP., EMISSION CONTROL, EXPENDITURES AND EQUIVALENT EMPLOYMENT, 1967-76

[Calendar year basis, dollar amounts in thousands]

Project	1967	1968	1969	1970	1971	1972	Projected 1973	Projected 1974	Projected 1975	Projected 1976
UNCONVENTIONAL ENGINE PROJECTS										
Research and engineering	$3,044	$7,437	$14,057	$18,113	$28,048	$30,502	$33,011	$31,444	$31,174	$30,750
Reliability, inspection and testing				94	2,037	2,163	1,707	1,926	2,560	3,112
Facilities and tools	1	55	284	7,149	962	3,482	11,268	15,858	21,448	34,457
Total	3,045	7,492	14,341	25,356	31,047	36,147	45,986	49,228	55,182	68,319
Memo: Direct expenditures in R. & E., etc.:										
Personnel	1,122	3,102	5,417	6,734	11,138	8,595	10,789	11,607	12,728	13,316
Material costs	519	1,601	2,636	4,351	5,643	9,907	11,314	8,695	8,511	8,241
Outside services		40	390	197	2,038	2,163	1,444	1,945	1,124	568
Other costs			12	51	104	136	138	136	116	77
Subtotal	1,641	4,743	8,455	11,333	18,923	20,801	23,685	22,383	22,479	22,202
Total direct expenditures including facilities and tools	1,642	4,798	8,739	18,482	19,885	24,283	34,953	38,241	43,927	56,659
EQUIVALENT EMPLOYMENT										
Professional:										
Full time	37.0	94.0	116.5	171.1	189.5	186.9	185.8	186.3	191.6	196.7
Part-time additional equivalent	6.0	11.5	19.3	50.8	110.5	67.9	63.2	71.1	68.2	70.3
Subtotal professional	43.0	105.5	135.8	221.9	300.0	254.8	249.0	257.4	259.8	267.0
Laboratory technicians	24.0	62.0	94.5	105.5	119.8	148.0	138.6	155.1	159.5	173.9
Other technical and clerical	47.0	86.5	93.0	129.0	133.9	154.4	184.3	198.4	209.0	206.9
Total	114.0	254.0	323.3	456.4	553.7	557.2	571.9	610.9	628.3	647.8

Note: Rotary engine expenditures include only those related to emission control. The above data display a summary of expenditures for the years 1967 through 1972 and a projection through 1976.

FORD MOTOR CO., 1967-76 EMISSION CONTROL EXPENDITURES AND EQUIVALENT HEADCOUNT

Project number and description	Calendar year expenditures (millions)										Calendar year average equivalent headcount							
	1967	1968	1969	1970	1971	[1] 1972	1973	[2] 1974	[2] 1975	[2] 1976	1967	1968	1969	1970	1971	1972	1973	1974 [1] 1976 [2]
RESEARCH AND ENGINEERING																		
Variable effort:																		
1. R. & D. of systems designed for meeting 1975 Federal standards				$0.3	$2.0	$9.5	$30.7							16.	79	286	1,020	
2. R. & D. of systems designed for meeting 1976 Federal standards		$0.1	$0.3	.4	1.2	3.3	7.0					3	15	18	47	115	262	
3. R. & D. of systems designed for meeting 1974 California standards		(3)	(3)	.6	3.4	16.1	23.7					1		26	143	546	880	
4. Catalyst component research standards	$0.4	.5	.6	.9	1.9	2.7	1.5				18	27	29	49	79	117	54	
5. Reactor manifold component research	.2	.4	.3	.6	1.3	.9	.2				11	15	15	28	52	27	4	
6. EGR system research	.1	.2	.2	.3	.9	1.0	.9				5	12	9	14	34	36	35	
7. Ignition system component research	.1	.2	.2	.7	.9	.5	.5				8	11	19	35	27	18	18	
8. Other basic engine research	1.0	.6	.8	.4	.3	.2	.6				55	32	40	17	12	7	21	
9. Induction and fuel system component research	.9	.9	.9	1.5	1.9	2.1	1.6				50	43	48	77	67	65	52	
10. Fuels and lubricants research	.2	.4	.3	.4	.4	.5	.5				7	17	12	16	13	12	10	
11. Research in physics and chemistry related to HC, CO, NO_x	.1	.1	.1	.3	.2	.1	.1				6	4	7	13	8	4	5	
12. Alternate power source research	4.8	4.9	6.6	8.0	13.0	20.2	24.5				194	219	240	253	318	446	567	
13. Research on potential internal combustion engine emissions	(3)		(3)	(3)	.1	.1	.1							1	1	2	3	
14. Testing and data analysis research	.2	.3	.8	1.1	2.4	3.4	3.2				7	26	57	61	106	135	129	
15. Evaporative emission research	.4	1.0	.7	.4	.7	1.2	2.0				22	59	34	21	29	49	83	
16. Crankcase emission research	(3)	(3)		(3)	.1	(3)									1	1		
17. Closed-loop emissions research	(3)	(3)	(3)	.1	.3	.7	2.1					1	1	3	9	15	76	
18. Emission development certification, and production emission engineering	1.1	1.5	1.7	2.2	8.5	12.3	19.7				68	103	104	123	405	550	805	
19. R. & D. in support of production exhaust emission control	5.6	5.9	9.4	12.7	19.2	18.2	9.7				298	296	493	684	874	680	381	
20. Air quality research	.1	.3	.4	.6	.7	.8	.8				2	4	4	9	8	9	9	
21. Coordination and communication	.1	.4	.7	1.3	1.0	.9	1.5				4	10	32	37	29	27	39	
Total variable effort	15.3	17.7	24.0	32.8	60.4	94.7	130.9	138.7	$147.0	$155.9	755	883	1,159	1,501	2,345	3,147	4,453	4,453
Support effort	8.1	8.6	12.3	18.7	29.9	36.0	50.2	53.3	56.5	59.8	315	318	389	517	752	881	1,148	1,148
Total research and engineering	23.4	26.3	36.3	51.5	90.3	130.7	181.1	192.0	203.5	215.7	1,070	1,201	1,548	2,018	3,097	4,028	5,601	5,601
Other emission control expenditures:																		
Tooling	7.6	6.3	9.9	4.8	10.9	14.1	87.9	107.0										
Facilities	16.2	2.8	4.2	9.2	27.2	14.2	68.0	100.0										
Launching	3.5	.2	2.3	1.5	3.5	3.2	12.6	32.3										
Total other emission expenditures	27.3	9.3	16.4	15.5	41.6	31.5	168.5	239.3										
Total expenditures	50.7	35.6	52.7	67.0	131.9	162.2	349.6	431.3										

[1] Excludes 1973 model recertification.
[2] 1974-76 research and engineering cost and manpower levels are projected equal to the 1973 projection, adjusted for anticipated inflation.
[3] Less than $50,000.

Note: Headcount includes salaried, agency, hourly and overtime equivalent personnel.

FORD MOTOR CO., 1967-73 EMISSION RESEARCH AND ENGINEERING VARIABLE, EXPENDITURES AND EQUIVALENT HEADCOUNT

PROJECT: 12—ALTERNATE POWER SOURCE RESEARCH

[Dollar amounts in thousands]

	1967	1968	1969	1970	1971	1972	1973
Expenditures:							
Personnel	$2,091	$2,584	$2,878	$4,427	$6,018	$9,096	$11,208
Material	1,422	1,057	2,414	3,054	3,471	7,342	7,069
Purchased services:							
Inside	851	818	1,099	335	880	1,939	2,604
Outside	448	406	173	153	303	1,817	3,651
Other expense					2,322		
Total expenditures	4,812	4,865	6,564	7,969	12,994	20,194	24,532
Equivalent headcount:							
Salaried	192	212	228	234	286	393	488
Agency			1		1	8	4
Hourly				5	12		
Overtime	2	7	11	14	19	45	75
Total equivalent headcount	194	219	240	253	318	446	567

CHRYSLER CORP.

EMISSIONS CONTROL DOLLAR RESOURCES AND PROFESSIONAL TECHNICAL MAN-YEARS, CALENDAR YEARS 1970-74

[Dollar amounts in millions]

	1970 actual		1971 actual		1972 actual		1973 estimate		1974 estimate	
	Resources	Professional technical man-years	Resources	Professional technical man-years	Resources	Professional technical man-years	Resources	Professional technical man-years	Resources	Professional technical man-years
Engine modification	$3.7	166	$4.2	170	$5.3	233	$8.5	320	$9.8	370
Electric engine control	.4	12	1.0	38	1.1	48	1.5	60	3.2	120
Thermal reactors	1.9	79	3.0	101	1.9	84	2.0	75	2.3	85
Catalytic reactors	1.4	70	3.5	114	7.0	305	12.6	475	13.0	490
Alternative propulsion systems	.1	2	.3	11	.8	35	3.9	145	6.0	225
Total	7.5	329	12.0	434	16.1	705	28.5	1,075	34.3	1,290
Administrative support	1.2		1.4		2.5		2.8		3.0	
Total	8.7		13.4		18.6		31.3		37.3	
Capital expenditures	.3		1.0		1.2		15.2		12.5	
Total resources	9.0		14.4		19.8		46.5		49.8	

Note: These figures have been prepared by using analysis techniques and are not taken from official books of record.

Mr. DITLOW. We feel those figures are inflated in the sense that they take into account costs which are not genuinely part of basic research and development. They include costs of tooling and the certification work of the motor vehicles themselves.

We have never seen a specific breakdown of their expenditures other than a large sum—like Chrysler says $3.9 million on alternative research and GM says $10 million on alternative research. We would like to see a specific breakdown as to what they are spending on each of the various versions.

Perhaps this would give this committee a better handle as to what areas are being neglected by the auto companies. Where they say they are spending $100 million on catalyst development, obviously that includes a lot of tooling up and production facilities. Those areas are being vastly overstated. In the estimate of GM, other research and development exceeds research and development on alternatives by 10 to 1.

Mr. NASH. Perhaps an inquiry directly to the auto companies on the details of their expenditures might be in order.

Mr. SYMINGTON. We will have an opportunity to question the spokesmen of the auto industry later, and your proposal is probably a pretty good idea.

Mr. BROWN. Mr. Chairman, I do not want to take up additional time with questions but there were some additional points on which I think we might elicit information. I would like to inquire if the gentlemen would be willing to provide us with responses to written questions.

Mr. DITLOW. We would be more than glad to do that.

Mr. SYMINGTON. Thank you both very much.

Our next witness is Dr. Robert F. Sawyer, professor of mechanical engineering at the California University at Berkeley. Dr. Sawyer has conducted extensive research in fields related to ground propulsion systems. He has been a consultant to the EPA, the Department of Transportation, and the National Academy of Sciences; and currently, Dr. Sawyer heads the technology panel of the National Academy of Sciences' Committee on Motor Vehicle Emissions.

On behalf of the subcommittee, I welcome you, Dr. Sawyer, and look forward to your testimony.

[A biographical sketch of Dr. Sawyer follows:]

DR. ROBERT F. SAWYER

Dr. Robert F. Sawyer is a Professor of Mechanical Engineering at the University of California (Berkeley). He teaches undergraduate and graduate courses and conducts research in the areas of combustion, propulsion, thermodynamics, energy conversion, air pollution, and fires. He currently is investigating non-equilibrium combustion phenomena under an AFOSR grant, basic combustion characteristics related to air pollution, and fire safety for the National Science Foundation. His consultant activity includes work for the EPA, NATO, DOT and the National Academy of Sciences.

Dr. Sawyer is an associate fellow of the American Institute of Aeronautics and Astronautics, a fellow of the British Interplanetary Society, a member of the American Society of Mechanical Engineers, Combustion Institute, Air Pollution Control Association, American Chemical Society, Society of Automative Engineers, American Society for Engineering Education, Sigma Xi, Pi Tau Sigma, Tau Beta Pi, and is a Registered Professional Engineer in the State of California. He serves on the editorial board of Combustion Science and Technology and is

chairman of the Western States Section of the Combustion Institute. He serves on the Advisory Committee on Alternate Automotive Power Systems (President's Council on Environmental Quality), and heads the Technology Panel of the National Academy of Sciences' Committee on Motor Vehicle Emissions.

Among Dr. Sawyer's publications are papers and reports in the areas of heat transfer, missile systems, propulsion, propellants, chemical kinetics, combustion, air pollution, and fires. He is coauthor of the book, "The Performance of Chemical Propellants."

Dr. Sawyer studied at Stanford University in the Department of Mechanical Engineering (B.S., 1957, M.S., 1958). His later graduate and doctoral degree work was at the Guggenheim Aerospace Propulsion Laboratories of the Department of Aerospace Sciences at Princeton University (M.A., 1963; Ph.D., 1966). He served as a Rocket Propulsion Research Engineer and Chief of the Liquid Systems Analysis Section at the Air Force Rocket Propulsion Laboratory (1958-61).

He was born in Santa Barbara, California, on 19 May 1935. Dr. Sawyer served as an officer in the U.S. Air Force. He, his wife, Barbara, and daughters, Lisa and Allison, live in Walnut Creek, California.

STATEMENT OF DR. ROBERT F. SAWYER, PROFESSOR OF MECHANICAL ENGINEERING, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIF.

Dr. SAWYER. Mr. Chairman and members of the committee, I am honored to have been asked to testify before you on H.R. 10392 dealing with research and development on ground propulsion systems. I would like to emphasize that I am speaking as an individual this morning and that the comments which I shall make do not necessarily reflect the views of the National Academy of Sciences' Committee on Motor Vehicle Emissions, or the technology panel—of which I am the chairman—of that Committee. This group is currently involved in a study which is not yet complete. Our conclusions will be delivered to the Congress and the Senate, and I do not in any way want to prejudge the final conclusions in my remarks.

Similarly, although I have been a member of the Advisory Committee on Advanced Automotive Power Systems, Council on Environmental Quality, for the past 3 years, my remarks are again my own and do not necessarily reflect the views of that committee.

I do hope that my perspective of ground propulsion technology and its needs in the United States will be useful to the committee. Unfortunately, there are only a small number of individuals in our country who work in the field of automotive propulsion technology and are not associated with the automotive industry or its suppliers. I myself encountered difficulty in finding consultants to work for me and the National Academy of Sciences who are indeed independent of the industry.

My remarks will be brief, and they will focus upon the status of automotive engine technology and my concerns that this technology is neither adequately meeting the needs of the United States nor satisfactorily answering the challenge of impressive foreign competition.

First, does the Federal Government have a legitimate role in the field of automotive propulsion technology? It has been suggested by some that the automotive industry is more than adequate to the task of advancing automotive propulsion technology, and that the combined forces of public pressure, the marketplace, federally mandated incentives, or possibly a combination of these is sufficient to bring about positive advancements without direct involvement by Federal agencies

in the technology itself. I wish to challenge that view. It is a view which has been expressed not only by the auto industry but also, I believe unfortunately, by representatives of the Federal agencies, as Chairman Symington has already noted, which appeared before earlier hearings of this committee.

This approach as it has been applied to automotive emissions technology has been most discouraging. Only 25 years after the recognition of the problem are we beginning to see significant advances in the control of automotive emissions. Even now, serious questions remain regarding the effectiveness of the control technology which our automobile industry has chosen, especially when these vehicles are placed in the hands of the public. No argument exists that the control of automotive emissions represents an immense expense to the public. I am personally very uncomfortable that these expenses are being invested in a technology which is neither optimum nor cost-effective and that federally mandated controls have been specified from a very shallow technological base of understanding within the Government.

Whenever the public welfare is strongly involved, the Federal Government should take a responsible, active position. Automotive propulsion technology impacts strongly upon public safety, conservation of resources, the quality of the environment, and the economic health of the Nation and therefore should be a legitimate concern of the Federal Government. Strong Federal roles in such technologies as aeronautics, atomic energy, astronautics, and health care have clearly been in the interest of our country and have yielded substantial public benefit. A large increased investment in energy technology has been initiated, and will be part of the ERDA program. Automotive propulsion technology should receive a similar response from the Federal Government.

Even if the concept of an appropriate Federal role limited to regulatory activity were accepted, it is important that a strong technological competence, independent of the industry to be regulated, exist. No such technological base for making sound regulatory decisions exists in the United States. What I am saying is that all of the technology or practically all of it is invested in the auto industry. It is in the public interest that a more active and substantial contribution be made by the Federal Government in automotive propulsion technology. Current expenditures of a few millions of dollars annually are completely inconsistent with the importance of $100 billion industry or even the several billion dollar annual cost of automotive air pollution control systems alone.

With the energy crisis and resulting long overdue concern with the poor fuel economy of the American automobile, an unfortunate misconception exists that improvement in automotive fuel economy, emissions, and performance cannot be pursued simultaneously—that improvement in one characteristic must necessarily be at the expense of the others. Although to date this unfortunately appears to have been the result of the approach of the U.S. automobile industry to emissions control, there is no reason why such tradeoffs are necessary. One should also note the overwhelming importance of vehicle weight upon fuel economy. If we are serious about improving fuel economy, then attention must be focused primarily upon reducing the weight of the vehicle. Until this is done it is specious to express concern over the fuel economy costs of air pollution control. They are minor. But the

technology or assuring the safety of lighter weight vehicles does indeed require special technical attention. The good fuel economy of lower weight vehicles indeed makes the task of meeting emission control standards much easier.

The U.S. automobile industry excels in manufacturing technology and marketing and is to be credited with making the automobile within the means of the vast majority of American families. It is unfortunate that advanced manufacturing technology is used on what remains a low-technology product. These terms, of course, are relative and require some clarification. Perhaps it is easiest to draw a comparison with the aircraft as the contrasting example of a very high technology product and one, in which, not by chance, Federal investment in technology played a major role. Examples also exist which combine advanced manufacturing technology with a high technology product, the U.S. electronics industry providing an excellent case in point. Most of the technology of today's automobile is largely unchanged from that of 50 years ago.

Unfortunately it is the foreign automobile industry which is leading the way in bringing advanced technology to the production state. I am disappointed personally that we must go to foreign manufacturers in order to be able to purchase economical cars with fuel injection, electronic controls, automated diagnostic equipment, diesel engines, non-catalyst-based emission control systems, and, soon, the first of the stratified charge engines.

Mr. SYMINGTON. I can add something to that because the Toyota people and one other company have sent to this country for demonstration tests, a safety vehicle with specially manufactured bumpers and all kinds of interior equipment which is supposed to be able to withstand a 50-mile-per-hour crash. Yet, it is still a light car.

Dr. SAWYER. It is certainly not impossible to make a lightweight safe vehicle. It is, however, more difficult to make a large lightweight safe vehicle.

I am similarily dissatisfied with the U.S. automotive industry for giving 15 percent of the U.S. market in 1973 to foreign manufacturers; actually it reached 17 percent in January of this year. Apparently it has occurred simply because of a decision to emphasize production and marketing of large inefficient automobiles.

Frankly, I have no clear understanding of why the U.S. automobile industry is unable to or perhaps unwilling to advance propulsion technology more rapidly. One cause is probably the size itself of the U.S. automobile industry. The large investment in manufacturing equipment required to make more than 10 million automobiles per year is not easily or reasonably subject to rapid change. I have heard representatives of the automobile industry state that their investment in emission control technology is so great that remaining funds for propulsion technology development are inadequate. I frankly do not believe that statement. Whatever the reason for lack of progress by the industry, the need and justification for a more substantial and active contribution by the Federal Government is apparent. The answer to the first question raised is then, "Yes; the Federal Government does have a legitimate and important role in the field of automotive propulsion technology."

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Second, how should this Federal role be fulfilled? I do not have an answer to this question but would strongly support the authors of this legislation in their observation that NASA, particularly the Lewis Laboratory in Cleveland, has an outstanding, demonstrated technical competence which could well be employed in a Federal program dealing with research and development on ground propulsion systems. The administrative and technical leadership which Mr. John Brogan, who appeared before this committee in February, of the Environmental Protection Agency has demonstrated in his organization and execution of the alternative automotive power systems program is praiseworthy and this program and key personnel should be part of any Federal automotive propulsion program. The likely activation of ERDA does not diminish the need for the proposed work but does appear to complicate the administrative structure of this legislation.

I appreciate this opportunity to speak before your committee and welcome your questions if I can be of further assistance.

Mr. SYMINGTON. I certainly thank you Dr. Sawyer for your statement. It gives us something to think about here.

Mr. Brown, do you have any questions?

Mr. BROWN. I just wish to express my appreciation for this testimony, also. I think it is excellent. I would like to be able to submit some questions in writing at a later date if it is possible to do so.

Dr. SAWYER. I would be quite willing to accept those. I have avoided technical details in my presentation and, since that is my field, if you have technical related questions I would be happy to answer them.

Mr. BROWN. I note your point as to the strong impact on the public welfare by the automotive industry and the comparison with other areas in which the Federal Government has taken a role such as the health care system and, of course, the technical fields of aeronautics, atomic energy, and astronautics. I was intrigued by your reference to the health care system because the Congress has been deeply involved now for some years in trying to rationalize the national health care system, which again is a major industry in this country, perhaps in the $100 billion range, and with a very large group of dedicated professionals whose commitment is to the public welfare, and yet the public welfare does not seem to be as adequately served as it should be. I think this is a very close comparison with the situation in the automobile industry.

Automobile companies, as with the doctors, are becoming quite wealthy and have been among the more prosperous elements of our society. Yet, we find transportation and health being areas of increased Federal concern. I am intrigued why this should be so just from a philosophical point of view. What is wrong with our great systems of supplying these human and technical services which does not allow us to meet the needs in a more effective fashion. You may wish to comment on that although it may require greater time than is available.

Dr. SAWYER. That is certainly a field in which I am not active but I would point out that Federal assistance to technological innovation and health care has been substantial. We now begin to see engineers working on health care systems which I think is a very productive effort and the Federal contribution has been very useful.

I would like to add one thing, one parenthetical remark regarding the very impressive Japanese advancements in the automobile technology field.

As an engineering educator I find that both the Japanese Government and industry send excellent students to my university to study for a period of 1 to 2 years, fully paid by their companies or the Government itself. These students return to Japan to play an active role in the development of these very advanced technology engines which are so interesting at the present time. I have never had a student paid by the U.S. automobile industry come to study at our university.

Mr. SYMINGTON. There were echoes in your testimony, and in some of the preceding testimony, of something that was mentioned 4 or 5 years ago in our Science and Technology Panel which appears annually before the Science and Astronautics Committee and is given a general subject to address, such as "Technology and the Urban Crisis." I think that is the one at which John Gardner was the keynote speaker, and other public figures from all over the world were also in attendance. There was one gentleman who pointed out that Henry Ford with his Model T had prepared a stock chassis that could accommodate whatever improvements in engines and comfort over the years would likely come along. That seemed to be a fairly good way to have a car for a long time, too. Then he said that Alfred Sloane came along with the idea of the annual model change so that people would be dissatisfied with last year's cars and would want this year's car. And this caused a competition in cosmetic changes, changes in the appearance of cars but not a tremendous amount of energy was expended in other technical improvements. Chrysler did have a few things that came along like the overdrive and certain engine improvements but they did not really address themselves to safety. I think the one car that was built for safety was a big bomb, the Tucker. People sort of laughed even then at the idea of technology for safety. And why were they allowed to laugh? The companies laughed with them. They did not caution themselves and society that this is something we probably ought to think about, even when annual deaths would go from 20 to 50,000 and the injuries and the maiming and the tragedies would be many times more than that.

So finally we have reached a point where society has decided to address itself to these things and what we are looking for is the right relationship; that is, between Government, industry, and the people. It was testified earlier today that people will generally accept what they are encouraged to believe is available with minimum discomfort and danger. It is not fair to stand back and say well, we are just giving the people what they want. They have to know what the true alternatives would be, given an aggressive technology, to be able to make a concise and informed decision intelligently as to what they want. Would you agree?

Dr. SAWYER. Very much so, and I think we are quite fortunate in having the foreign competition to give the American buyers a choice.

Mr. SYMINGTON. You see, the pressures on people in elective office are very great to extend their enthusiasm for sudden change, or even slow change, because we are warned about the dislocations which would affect the stock market and the industry itself. And, of course,

the labor unions, although they consist of consumers also, they fear the greater danger is the kind of distortion in the economy forced on the industry by demands from the Government which would cause them to lose jobs. The independent dealers and the oil companies generally point out the hazards of auto emission controls because it adds to the price of the car and reduces fuel economy. I think you have stated you do not think that is the major reason for increased costs but they insist that it is.

And so, it is a bit of a dilemma. There is a great deal of reluctance in the national community to accept changes insisted upon by the Federal Government in their lives and in this area particularly. The Federal Government can really break its pick in its attempt to assist on changes; the people who insist on those things will get bumped out of office because they are making impossible demands on the taxpayer and the consumer—impossible, at least in the range of their understanding. They cannot accept these things.

So, really it comes down, in one sense, ironically, to a substantiation of DOT's opinion that the auto industry has the action because without a conscientious approach to the resolution of these problems, it is almost outside the capacity of Government to deal with them effectively. They have to, really, in one sense, come from the industry. The industry has to welcome and encourage scientific and technological innovations within its own ranks. It has to be willing to devote a considerable portion of its profits to improving the cleanliness of the car, the engine safety of the vehicle, and so forth. It has to pretty much do it whether the public asks for it or not because we know the public will not ask for it as long as they are concerned about cost and as long as we can keep the death level down to 50,000 a year in a nation of 200 million people, people just have not reached a threshold of resistance to that pattern.

So, I think even you would agree, wouldn't you, that the automobile industry has a tremendous responsibility and, regardless of all the argumentation we have been presented with, they have not really yet met it.

Dr. SAWYER. The automobile industry, of course, has the huge resources which will have to be brought to bear to solve the technological problems. I think the Government can, at best, hope to provide some leverage to move the technology by demonstrating that there are alternatives which may be better. And the public then seeing these alternatives will in turn demand that the automobile industry bring them into production.

Mr. SYMINGTON. The industry insists that the demands Government makes on them—of course, they would include in that any tax we place on the inefficient car—are causing higher prices for cars. They go to their consumers and say, "Look what the Government is doing to us, to you. We have to charge another $100 a year." But aren't you saying that if they retooled for a smaller car, considering the effect of added weight on the efficiency of the car and on the cost of the car initially, because of materials, that they could probably bring car costs down to a point where with the addition of the latest state-of-the-art in auto emissions and in safety, that it would still be within the general and expectable range of cost to the consumer.

Dr. SAWYER. Yes. I think with a move toward a smaller car one has a much more economical car both in the first cost and in the operat-

ing cost. I think it is unfortunate that the consumer is not forced to pay for his entire gasoline supply for 100,000 miles before he buys the car because perhaps that is the only way one can drive home the expense of the gasoline, which now about matches the initial cost of the car.

Mr. SYMINGTON. It seems to me they are kind of hanging on for some reason. If you look at the TV adds of the major automobile manufacturers, for a while they were very quiet about their large vehicles but now they seem to have gained back some of their old enthusiasm saying, "You know, there are some families who have to have at least a medium-size car and some do better with a big car." Then they throw in some eye wash. In the end, as a matter of fact, they suggest the large cars are really more efficient and economical, and "try it, you'll like it," that sort of thing, making the public say, "well, I guess everything is all right, King Faisal is behaving again and we'll have a decent friendship and I want to get a big car."

I suppose we will have a chance to ask the spokesman for the automobile industry why they think that is a fruitful approach at this particular time.

Dr. SAWYER. I am certain the answer is that it is a comfortable approach. They know how to make profits with that type of market and it is simply what they are used to doing.

In being critical of the auto industry, I am also in not too veiled a fashion critical of some of the Government agencies who are responsible for regulating the auto industry. I think many times they view only the control functions and do not have an adequate background in the technological aspects to specify controls which indeed will accomplish what they set out to accomplish. It is important to assure there is a base of good technological competence within the Government control agencies. One way to do this is to have the Government involved in research and deelopment technology. Automatically there then are experts within the Government available to the control agencies.

Mr. SYMINGTON. Counsel would like to ask a question.

Mr. HAMMILL. One of the earlier witnesses before the subcommittee from the Department of Transportation indicated that the Federal Government should not attempt to duplicate, nor could it reasonably be expected to duplicate, the enormous resources of the automobile industry. I think his testimony was to the effect that what the Government really should do is try to provide incentives to the industry to make all of these changes in terms of fuel economy and pollution control. But your statement indicates that most of the technological advances in recent years have been made abroad and not in this country.

It seems to me that one big incentive would be provided by the fact that the car manufacturers from abroad are making these advances. It seems to me that alone should bring a lot of competitive pressure on the domestic automobile industry. I do not quite understand why that has not happened. Do you have a theory?

Mr. SAWYER. I am quite certain it has not happened in the past because they are addressed to different markets. The foreign automobiles have been predominantly small, usually low performance vehicles. The American automobile industry has not, until very recently,

tried to compete in that market. They have simply been very happy to take on the large car market, and let the small car market go to the foreign manufacturers. So I do not think there really has been a direct competition, just in the overlapping region where people move from the large American car to the small foreign car.

Now, indeed all of the large manufacturers have cars in this size range which are in fairly direct competition with the foreign cars. This is only a very recent advent and these cars indeed will have to compete on a technologically comparable basis or they will not be successful.

I do not mean to imply that Detroit has no advanced technology ready to go. I have visited Detroit on numerous occasions during the last 6 months. I am going to Japan next month. I have seen in Detroit substantial advances especially in the field of stratified charge engines. When these will come into production though seems to be a very questionable thing. I do not know what incentive can be provided to speed up this process.

Mr. SYMINGTON. Of course the Clean Air Act was an incentive, but it has been weakened for what appeared to the Congress to be good and sufficient reasons, pressed by the auto industry, indicating their inability to make these accommodations until later on in the seventies. That is an example of one kind of leverage we can impose. It is a law saying you have to make it by this time period; and that appeared to be unrealistic and so we extended it. Another would be a tax of some kind on emissions which they would resist with the same intensity because it would have the same effect.

In a way we are just sort of feeling our way along here. We do recognize that the auto industry has its small car line, something I felt was long overdue, because for the last decade I have found it preferable to have a small car and have always found at least one American company which could produce one.

I hate to see a return to the big car psychology. I know people like to travel with all their kids but I have seen it happen in Europe that they're a little squeezed up in there, but they are there, and all their belongings are on the roof, I guess. Also, there are other ways of moving about, the idea of taking your car to a certain place on a train, or going and picking up a car. I am not sure that we have to go from coast to coast in cars, but those are just idle thoughts.

Dr. SAWYER. I agree with you completely and I think it is most unfortunate that the Federal Government lost the leadership role in promoting fuel economy by declaring that the energy crisis was over and not by establishing perhaps quotas on imports so that our self-sufficiency would be accelerated by keeping the American public away from inefficient automobiles.

Mr. SYMINGTON. The auto manufacturers would love that and the labor unions, too, but would they have been able to meet the difference? If we had insisted as a Government on cars of that size and weight, we would have run into, I think, insurmountable pressures. Of course, we are getting into another area of hypothesis now, but I think it is a good thing that we did not cut imports. We might have found ourselves becoming satisfied with what we were able to produce here profitably regardless of the nature of the vehicle produced.

Dr. SAWYER. I meant import of fuel.

Mr. SYMINGTON. Excuse me.

Dr. SAWYER. That is to sustain the shortage of fuel to encourage the public to think more about fuel economy.

Mr. SYMINGTON. I don't think that would have worked either.

Dr. SAWYER. Well, sir, sooner or later we will have a disastrous situation in which we simply run out of fuel, and it is better that we face it sooner and gradually, rather than precipitously.

Mr. SYMINGTON. I think, of course, the pressures on Government cause it, as sort of a natural survival instinct, to keep trying to reassure people that there isn't enough fuel. The other end of the spectrum would be to deliberately withhold fuel and see how tough it is. That would last a very short time, I think; certainly one congressional election's worth. [Laughter.]

Mr. Brown?

Mr. BROWN. I was going to comment along a similar line. I think that we only seem to be able to make large-scale policy decisions under the impact of some crisis. The impact of the aborted fuel crisis did result in the largest shift in demand for small cars that this Nation has probably every seen.

But that crisis, as you correctly point out, will be with us for a much longer time. It needs to be viewed in its totality.

I have no feeling that we cannot cope with this if we merely recognize that we have to. I think back to the period during World War II in which overnight we ceased the production of all automobiles and transformed the companies to building tanks and airplanes. Now, we don't want to build tanks today, but we might want to build small automobiles. It can be easily done if there is a sense of national urgency about it and some degree of leadership which, as other witnesses have testified, has not been forthcoming from this Congress. But it has not been forthcoming from a lot of other places either. It is my hope that this vacuum of leadership can be filled and we can help to create a sense in the American public of the things which need to be done. I am completely confident that if the American public is aware of what needs to be done—and American industry—that they can do it. There is no lack of capability to do these things.

Mr. SYMINGTON. The gentleman has called to mind William James' suggestion that we need a moral equivalent to war in order to do the right thing during peacetime. We need to make peace a heroic venture, and I suppose a certain amount of heroism is involved in trying to discipline ourselves in this fashion.

I think even the auto industry as it looks ahead 40 years—as I said earlier, that is a long time, and an awful lot of people will retire before that time on their pensions—but they will certainly have other forms of propulsion by that time one way or the other. The sooner the better because we have to get here from there. We have to get into the 1980's with some confidence that people can propel themselves around in satisfactory vehicles, and the purpose of these hearings is to determine whether or not the right kind of thought is being given to this.

Mr. BROWN. May I just inquire, Mr. Chairman, of the witness with regard to the timing of the National Academy of Scences' study with which he is connected. Do you expect that to be forthcoming shortly?

Dr. SAWYER. There are several National Academy of Sciences' studies. The one which I am associated with addresses emission stand-

ards and the fuel economy costs of meeting emission standards. It is to be delivered to the Congress on the 1st of October.

Mr. BROWN. Is it the one commissioned by the Senate?

Dr. SAWYER. Yes, to guide them in possible changes of the auto emission standards.

Mr. BROWN. On the health effects?

Dr. SAWYER. No, purely with the technology of automotive emissions control.

Mr. BROWN. Is there a separate study on health effects?

Dr. SAWYER. Yes.

Mr. BROWN. But the study is also due, as you indicated, in October?

Dr. SAWYER. I believe so. And there is yet a third study in the area of cost benefits which I believe is due a month before that.

Mr. BROWN. So all three studies will actually be forthcoming then by early fall?

Dr. SAWYER. Yes.

Mr. BROWN. Thank you.

Mr. SYMINGTON. Thank you very much, Dr. Sawyer, for your testimony.

The committee will meet again tomorrow at 10 a.m. in this room. Tomorrow will be "Industry Day." The subcommittee will hear the testimony of representatives of major automobile manufacturers.

Today's meeting is adjourned.

[Whereupon, the subcommittee was adjourned at 11:45 a.m., to reconvene Wednesday, the 12th of June 1974, at 10 a.m.]

RESEARCH ON GROUND PROPULSION SYSTEMS

WEDNESDAY, JUNE 12, 1974

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to adjournment, in room 2325, Rayburn House Office Building, Hon. James W. Symington (chairman) presiding.

Mr. SYMINGTON. The subcommittee will be in order.

This is the second day in our current set of hearings on H.R. 10392, a bill to authorize NASA to conduct research on ground propulsion systems.

We have invited representatives of the major U.S. automobile manufacturers to testify on the research and development activities of their companies, looking toward the development of improved engines in terms of fuel economy, clean emissions, and performance.

We also want to explore with them the appropriate role of the Government in research of this type.

We will begin by hearing a statement by Mr. Sydney L. Terry, vice president, Corporate Responsibility and Consumer Affairs, of the Chrysler Corp. Welcome, Mr. Terry; will you introduce your colleagues?

[A biographical sketch of Mr. Terry follows:]

MR. SYDNEY L. TERRY

Sydney L. Terry, vice president, public responsibility and consumer affairs, directs Chrysler Corporation's automotive safety relations, environmental relations, and consumer affairs programs. The office he heads also keeps the company alert to its policies and responsibilities in such areas as customer service and energy conservation.

Appointed April 1, 1974, he had been vice president, environmental and safety relations.

Terry's work and academic background includes:

Vice President, Environmental and Safety Relations, July, 1971-March, 1974.

Vice President, Safety and Emissions, May, 1970-July, 1971.

Vice President, Engineering, January, 1968-May, 1970.

Director, Engineering, 1968.

Director, Engineering Operations, 1966.

Executive Assistant to Group Vice President; International Operations, 1961.

Director, Corporate Product Planning, 1959.

Executive Assistant to Director, Corporate Product Volume Planning, 1958.

Chief of Section, Engineering Product Planning and Programming, 1956.

Chief of Section, Engineering Management Planning, 1956.

Chief, Interior Styling, 1956.
Department Head, Color and Fabric Studio, 1952.
Assistant Chief Engineer, Dodge Division, 1950.
Laboratory Engineer, Gear Functions, 1946.
Project Engineer, Development Design, 1945.
Project Engineer, Engine Installation Modification Center, 1944.
Project Engineer, Aircraft Engine Design, 1941.
Student Engineer, Chrysler Corporation, 1941.
Master of Science, automotive engineering, Chrysler Institute, 1943.
Bachelor of Science, engineering, Stanford University, 1941.
Central High School, Tulsa, Okla.

Terry is a director of the Society of Automotive Engineers and a past chairman of its Technical Board. He is chariman of the Engineering Advisory and Safety Standards committees of the Motor Vehicle Manufacturers Association (MVMA). He belongs to the Engineering Society of Detroit and serves on the advisory board to the University of Detroit College of Engineering and the board of directors of the National Safety Council.

He is a member of Phi Beta Kappa and Tau Beta Pi honorary societies.

He belongs to Delta Tau Delta fraternity, the Detroit Athletic Club, Otsego Ski Club and the Country Club of Detroit.

Terry was born April 5, 1920 in Huntsville, Alabama. He is married and has six children. The Terrys reside in Grosse Pointe Farms, Michigan.

STATEMENT OF SYDNEY L. TERRY, VICE PRESIDENT, PUBLIC RESPONSIBILITY AND CONSUMER AFFAIRS OF THE CHRYSLER CORP.

Mr. TERRY. My name is Sydney L. Terry, and I am vice president for public responsibility and consumer affairs for Chrysler Corp. With me is George J. Huebner, Jr., director of research, product planning, and development staff. And on my right is Mr. Victor Tomlinson, staff attorney.

We welcome the invitation and opportunity to express our views on H.R. 10392, a bill authorizing NASA to build up research on ground propulsion vehicles. In your letter of invitation addressed to us you expressed a desire to review the work being done on conventional automotive engines as well as alternative concepts and the prospects for clean emissions characteristics, fuel economy, and performance.

Research and development work at Chrysler Corp. has increased steadily in scope and size over the 50 years of corporate history and Chrysler has had for many years what we believe to be a well-deserved reputation for superior research and engineering results.

Our primary business is automotive transportation and the results of our efforts in the fields of research and development have been directed toward the optimization of automotive vehicle systems and components. Extensive research and development work has gone on to improve the efficiency, durability, and driveability of automotive propulsion systems. When the role of automotive emissions in smog formation was first discovered, research was undertaken at Chrysler to determine possible means of controlling or eliminating undesirable components of exhaust gas. In addition, Chrysler took a leading role in the scientific work to develop measurements and testing methods in cooperation with the California authorities.

Research on alternate powerplants has been a continuous activity. We have explored the potential of new and hopefully superior engines and transmissions. We have utilized the successful results of this research and development in actual powerplants that can be manufac-

tured and sold, and that give the economy, convenience, safety, and durability our customers demand.

Research and development work has also been actively pursued in those other areas of automotive transportation requirements which are essential characteristics of the automobile business.

This requires, of course, that the automobile transport people and goods from one place to another safely and efficiently with the maximum of comfort. It requires that our customer's investment is appealing in its appearance and appointments, and that the customer receive the maximum benefit for his rather substantial investment.

The target of a major portion of research and development work done at Chrysler over the last half century has been the engine and drive train. The list of alternate engines carefully explored covers the range of every type and variation of powerplant being discussed today which can show promise for the future.

We have investigated diesels of various types, steam systems, rotary, Stirling engines, and gas turbines. We have considered radial, horizontal, stratified charge, and supercharged spark ignition engines, as well as L-type engines, overhead valve engines, two-stroke engines, four-stroke engines, and many others. Each has been subjected to careful scientific and technical research and development work. Each has been carefully compared on a point-by-point basis with the spark ignition piston engine, which is still the worldwide standard of comparison for automotive powerplants.

Work being done at Chrysler on conventional engines is concerned primarily with reducing undesirable exhaust emissions and, at the same time, improving engine efficiency. It is unfortunately true that these two objectives are sometimes counter to each other by natural laws which we can only try to circumvent but which we cannot change.

Thus, the increasing stringency of emissions regulations plus the weight increases due to safety regulations has resulted in a gradual erosion over the past few years of the basic fuel economy of U.S. cars. We have measured fuel economy deterioration of between 7 percent to 22 percent over the past 5 years, depending on the model and the particular fuel economy test.

Next year we expect to show a slight improvement overall in fuel economy due to our work on engine efficiency, the development of lower axle ratios, and wide-spread use of radial tires. But if the required NO_x emissions—NO_x, meaning oxides of nitrogen—continue to be lowered, according to present regulations, fuel economy will suffer. Fuel economy losses of as much as 20 to 30 percent have resulted with some of our advanced emission control systems aimed at meeting the 0.4 gram per mile NO_x requirement contained in the 1970 Clean Air Act.

An alternative variation of the conventional engine which shows promise of substantial economy improvement with good emissions is the stratified charge principle.

About 20 years ago, we began to work with Texaco on what came to be called the Texaco controlled combustion system, or TCCS, engine. Combustion is managed in the cylinder so that a rich mixture of fuel and air is injected into one zone of the cylinder and ignited. It burns rapidly and causes to burn at a lower temperature the more diluted mixture that spreads into the rest of the chamber. This varying mix-

ture and temperature produce fewer emissions than the uniform mixture in a conventional engine. This pattern of burning also uses some 25 percent less fuel than that of the conventional engine. But that advantage is sacrificed, as better fuel economy is a conventional engine is, as emission controls approach the stringency required by the 1977 standards. We do have a four-cylinder TCCS engine on a Cricket, and we continue to work with it.

The other type of stratified charge engine is the Honda version, which employs two burning chambers. A small amount of rich mixture is ignited in a small pre-chamber and fired like a torch into a larger quantity of lean mixture in the main part of the cylinder. We had looked at this principle off and on for several decades, but Honda was the first to apply the principle to a production vehicle. Honda announced about a year ago that it would soon offer for sale a four-cylinder stratified charge engine on its Civic model.

We signed an agreement with Honda last fall to study the Honda engine on two Civics and on adaptations to two 350 cubic inch V–8's, for Honda had begun to adapt the engine to a larger car. That adaptation was far from being ready to put on a mass-production line.

Building a new valve system—which means essentially rebuilding the whole top of the engine, as we are trying now to do for our six- and eight-cylinder models—is a delicate and time-consuming development process. Honda's success with a four-cylinder is of more inspirational than practical value as we try to apply the principle to a larger engine.

We are continuing to study both stratified charge engines. They have good advantages. They are cleaner. The TCCS engine can run on diesel fuel and kerosene as well as gasoline. But it does not get significantly better mileage than today's mileage of a conventional engine if it bears all the emission control equipment it needs—basically the same complement as the conventional engine does—to meet the 1976–77 emission standards.

Perhaps the most ambitious and farsighted powerplant research project ever undertaken by any automobile company has been Chrysler's work on the automotive gas turbine. We believe that it shows promise of meeting passenger car powerplant objectives in a way which give it substantial advantages over all other powerplants used today.

But in order to achieve those very significant advantages, it is necessary to depart completely from current automobile industry powerplant engineering and manufacturing principles and practices.

Such development work is necessarily a very costly long-term project. It requires not only scientific and engineering discovery and invention but will eventually require that new types of manufacturing and processing techniques be developed.

Much progress has been achieved on the gas turbine. In 1963, 50 experimental turbine cars were hand built and then loaned to randomly selected users throughout the country for their evaluation. We learned much during this 2½-year experiment. Drivers liked turbines and from the technical standpoint sufficient information was obtained to enable us to plan our future development steps in a logical manner.

As with all fuel burning powerplants, the turbine has had problems with oxides of nitrogen emissions. The turbine exhaust is very clean from the standpoint of unburned hydrocarbon and carbon monoxide.

However, even though oxides of nitrogen were only a fraction of those emitted by an uncontrolled spark ignition engine, they were higher than that permitted by the Clean Air Act of 1970—and for a number of years of frustrating work, it did not seem possible to lower them.

The EPA has recognized, on the basis of tests, that the oxides of nitrogen regulations levels currently required by the Clean Air Act Amendment of 1970 are more stringent than required for health or atmospheric conditions. Although EPA has publicly expressed this position no change in required NO_x levels has yet been made in the law. If the law is changed and a new NO_x standard in the area of 2 grams per mile is established, we believe that the automotive gas turbine will be able to meet such revised standards with an ample margin of safety.

In addition to our own continuing research we were granted a contract by the EPA's Advanced Automotive Power Systems Group approximately 1½ years ago to supply several of our latest turbine engines to serve as a baseline powerplant on which to evaluate the results of turbine component research done independently of Chrysler efforts. The initial objective of this contract was to meet the emissions requirements of the Clean Air Act Amendment of 1970 with a margin of safety of approximately 50 percent. In 1973, this objective was modified to include a requirement for substantial improvement in fuel economy over that of the spark ignition engine.

We are redesigning and upgrading the Chrysler engine. Initial component tests indicate that improved efficiency goals seem to be achievable.

As part of the effort under this contract the Lewis Laboratories of NASA, under an interchange agreement with EPA, is contributing to the aerodynamic development of turbine elements such as the compressor, turbine wheels, nozzles, and air passages. NASA's skill and experience in the fields of thermodynamics, heat transfer, fluid mechanics, and aerodynamics will contribute substantially to achieving program objectives.

We welcome NASA's interest in the automobile with enthusiasm and hope. Its work in aviation has given our aircraft industry such a good technical foundation that it leads the world in sales—the marketplace indicator of quality.

Until now, the automobile industry has had only its own research on which to grow. Under its own steam—or spark—it has given the United States the most responsive system for moving people in the world. But we have challenges now that we would be delighted to have NASA help us meet.

The impetus of the Clean Air Act—and lately that of the line at the gas station—demand that the development of many years be done in a few months. This is not a good way to rebuild a complicated machine.

NASA is very good at the sort of long-range basic research we need badly now.

We would like to have NASA's skill and experience. We cannot afford to follow all the directions in which research ought to be done. We have to be selective.

For example, we would like to know more about how to manipulate the burning in a cylinder or combustion chamber. We might be able to build a better stratified charge engine. We would like to know more

about the wear of parts in hotter engines or differently designed engines. We want to know more about different shapes of turbine blades to get the best fuel and air flow through a turbine. We need lower cost materials with which we can raise cycle temperatures to even higher levels for greater fuel economy.

We believe the automotive industry is then well suited to take the results of this research, and actually design and develop engines for mass production and deliver them to the public as a part of a desirable automobile. That is the function of private industry in our country.

The most effective way of achieving an automobile—or a variety—that is clean, efficient, and economical is a thoughtful division of research and development work between Government and industry. We do not want to compete with NASA. We like the working relationship we have with the EPA for research and development, and we hope, that if NASA is empowered to do automotive research our relationship with NASA will be as friendly and productive as it has been for more than a decade in the manned space program.

Thank you very much.

Mr. SYMINGTON. Thank you, Mr. Terry, for your very illuminating and thoughtful statement.

The research you do with EPA is, of course, largely directed toward solution of the emissions problems; is it not?

Mr. TERRY. They have added fuel economy into the requirements for the turbine. As I mentioned in my statement, the contract includes a requirement for a substantial improvement in fuel economy as well. It was added after the beginning of the program. Initially, the program was aimed at lowering emissions. But they also now recognized the importance of fuel economy.

Mr. SYMINGTON. Do you feel if NASA were to engage in this kind of long-range research that that would either be duplicative or counterproductive?

You testified you feel it would be helpful, but I would like to explore that point.

Mr. TERRY. No, sir. The EPA program is aimed at development of specific powerplants which can be put into cars now. They are tested with emission levels now and reach certain fuel economy levels now.

So if they actually have a car with an engine in it they say here is what we have done with our research. We do not think it would be duplicative in the sense we are talking about NASA doing long-range basic research to contribute to the solution of these problems.

Mr. SYMINGTON. Very good.

Now just for the record, how much are you spending annually in your work with EPA to solve the current problems of emissions and fuel economy?

Mr. TERRY. You mean the turbine work with EPA or all the work on alternate powerplants which is independent?

Mr. SYMINGTON. Would you give both figures, if you can?

Mr. TERRY. Yes. Plus the little bit we are doing with SES on steam was $3.9 million. That is independent of the EPA work. It is independent and does not go on our regular budget.

The amount we are spending for 1973 on the EPA contracts is $1.8 million. We expect to spend in 1974 $2.9 million.

Mr. SYMINGTON. That is the turbine?

Mr. TERRY. Yes. Plus the little bit we are doing with SES on steam powerplants. We are assisting SES.

Mr. SYMINGTON. It is $1.8 million for your work with EPA on turbine engines?

Mr. TERRY. Yes; $1.8 in 1973 and $2.9 in 1974, respectively. A few hundred thousand dollars of that is to SES, but mainly it is for the EPA program.

Mr. SYMINGTON. How many personnel of yours would be involved in that?

Mr. TERRY. I will have to ask Mr. Huebner.

Mr. HUEBNER. On EPA at present there are 66 people.

Mr. SYMINGTON. Looking at page 3 of your statement where you reviewed the various engine systems, in the first paragraph, just so I can understand it, is that kind of investigation included in the figure you gave me?

Mr. TERRY. No, sir.

Mr. SYMINGTON. If not, how much are you devoting to that?

Mr. TERRY. The top paragraph on page 3 is aimed at covering the wide range of investigations we have made on all kinds of powerplants over a long period of time. We try to confine ourselves to actual development and engineering work on engines which we feel have promise for utilization in the near-term future and which we think might be developed. Engines that have some chance of becoming practical in automobiles in the foreseeable future.

This rules out a great many of the kinds of powerplants which are listed there.

Mr. SYMINGTON. What would be a typical annual expenditure for that kind of short-term research?

Mr. TERRY. Our expenditure for alternate powerplants in 1973 was $3.9 million.

Mr. SYMINGTON. I understand now.

By the way, in the first paragraph on page 3 of your statement, you mention that each of the aforementioned systems has been carefully compared on a point-by-point basis with the piston engine. Is that comparison complete?

Mr. TERRY. In a great many cases, the engines are put on a paper study. We have people who have sufficient experience that we can take the results of such paper studies and say it is not worth doing any more development work on that engine.

Mr. SYMINGTON. In other words, you have already rejected some of the approaches which you were addressing?

Mr. TERRY. Yes, sir, at least for the present. You understand however, that we can always have future developments which can change our minds.

Mr. SYMINGTON. The $3.9 million is spent mostly on systems which you think have some potential for reasonably short-term exploitations?

Mr. TERRY. Yes.

Mr. SYMINGTON. So really you are not devoting very much, if anything, toward long-term engine research?

Mr. TERRY. I'm not sure I understand your question.

Mr. SYMINGTON. I think what you testified—or at least as I understand your testimony—that Chrysler spending about $3.9 million on automobile engine research—that is, alternatives to the piston engine—

but that almost all of that sum is spent on engine alternatives, which would seem to provide some hope of being employed in the near term?

Mr. TERRY. Yes, sir. Mr. Huebner would like to comment.

Mr. HUEBNER. Let's review some of these things from the past, Mr. Symington. For example, we spent several years working with fuel cells as a means of automotive propulsion. We are not working on fuel cells at the present time because they do not appear to be practical even in the long-range future from the automotive standpoint.

Many of these alternate powerplants come under that category. We are and have taken very long term projects. For example, we have been working very seriously on the automotive gas turbine for well over 20 years. This is a long-term project. We think it is approaching the time when the final decision can be made to put it into high volume production.

Mr. SYMINGTON. That represents 20 years of research on the turbine, and that is the research which is today at $3.9 million.

Mr. TERRY. That is a good part of the $3.9 million, plus the additional work being done for EPA.

Mr. HUEBNER. There are two distinct programs here.

Mr. SYMINGTON. Well, looking back over those 20 years, if you had known then what difficulties we would be having today with existing technology, would you have felt compelled to try to speed up that research, or do you think it was progressing as fast as it could consistent with the state of the art?

Mr. HUEBNER. I do not think it could have gone any faster than it did. I believe we have in a sense led the rest of the world, because most of the automotive turbines today being developed have a strong stamp of our research on them.

Mr. SYMINGTON. Why did you undertake that research 20 years ago? You were not under any sense of urgency, but you were interested and curious about a possible new approach to propulsion; isn't that true?

Mr. HUEBNER. We wanted a better powerplant. We wanted one which had higher efficiency, that had a cleaner exhaust, that had less maintenance, that didn't need oil changes, and that would be smoother and all of these things, so that the customer would have less expense and pasengers in the car could get instant heat.

All of those things were a part of the reasons as to why we finally settled, out of numerous choices which faced us, on the turbine as the best potential.

Mr. SYMINGTON. But of course, as you conducted that research, you were doing perfectly well with the powerplant you had, and there was no one pushing you to think anew.

Mr. TERRY. As a matter of fact, I think it is worth saying that when the decision was made to develop the turbine and we were well into the program, exhaust emissions was not recognized as a problem. It just happened that the turbine had a very clean exhaust. After the importance of the emissions came to be recognized and started to be a requirement for engines, the turbine was found to be so low it was very difficult to measure its hydrocarbons and carbon monoxide emissions.

As we pointed out in the testimony, there is still a substantial problem with meeting the NO_x levels if they remain as low as those

required by the 1970 Clean Air Act. This is a fundamental problem. When you lower NO_x emissions, you will lose efficiency. [Pause.]

George says, "Except in the turbine." But the fact remains that if you want a higher heat for combustion you will have more formation of NO_x. If you could find some way to get around the higher heat in the turbine you might be able to get around the NO_x problem. And you certainly could bring the emission much lower than you can with the conventional piston engine, particularly if the temperature within the turbine rises.

Mr. SYMINGTON. Yesterday a witness testified that the foreign auto industry appears to have led the way in recent years in bringing some advanced technology into the production state. He cited fuel injection and electronic controls, diesel engines, and stratified charge engines. What do you think of that kind of statement?

Mr. TERRY. I think the foreign situation is completely different from what we have in the United States. In the United States we are essentially a mass-producing and mass-selling industry. When we make an important change which applies to all of our cars we have a big problem of getting it into production in order to produce this kind of change on all of the cars we build. We are also extremely sensitive to cost.

When we consider new features for our cars we must evaluate the cost of these new features versus the salability of the product in order to satisfy ourselves that the additional cost can be recovered from our customers because of the additional value the customer perceives in these features. The fact remains that a great deal of the innovations such as fuel injection, stratified charge engines, and so on are costly items. And the customer does not perceive these features as being worth an additional $50 or $100, or whatever the cost might translate out to, in the car he buys.

So the U.S. manufacturer does not introduce such features into his car until he can sell them in the open marketplace.

On the other hand the foreign manufacturer is only selling a relatively small amount of cars in this country. So he has an entirely different problem. He is trying to get penetration to sell some cars. If he is selling 10,000 cars in this country and he doubles his penetration because of some feature, he has done very well. The feature has more than just justified itself in his view.

Mr. SYMINGTON. Have you done similar tests yourself here?

Mr. TERRY. In many places he has done it in the particular market he is already in so that he can offer the feature in this country. It is mostly on small cars that the feature comes to be an economical thing to do.

Mr. SYMINGTON. I would think the unit cost would be far higher if the foreign manufacturer did it just to penetrate our market. If he can do that, then why in the world can't we do it?

Mr. TERRY. He is selling a different size car also, which makes it an entirely different situation. We were discussing disk brakes, for example. We have had disk brakes on cars in this country for many years and the principle of the disk brake is not new.

But the fact remains that disk brakes have a cost penalty over the drum brakes. They are on our cars in very high volume now principally because they are required by the fade requirements in the safety standards. But they are really not needed by the customers in normal usage.

Mr. SYMINGTON. You mention on page 3 of your statement that weight increases due to safety regulations are partly responsible for the erosion of fuel economy. That brings up a very important point. Are these weight increases due to new kinds of bumpers or structural requirements?

Mr. TERRY. Bumpers are certainly an important part of it. They are adding approximately 100 pounds to the average car weight. We figure that all the equipment put on the car to meet the safety and emission requirements combined have added somewhere between 300 and 400 pounds to the average car.

Mr. SYMINGTON. You are taking, as a point of departure, a car of what weight?

Mr. TERRY. We are talking about a 1965 preregulation car not having these features required.

Mr. SYMINGTON. In other words you would not add 300 pounds to the lightest car? Would it be the heaviest or the medium size?

Mr. TERRY. That is then the average. You do have the problem you point out that the passage of time alone would probably have caused an effect on weight regardless of regulations.

What we have tried to indicate is the weight in the car we have now which we feel is due to safety and emission regulations and which would not otherwise be in there had it not been required.

Mr. SYMINGTON. The argument has been made in previous testimony, or it has been suggested, that perhaps we should build smaller and lighter but stronger cars. For example, I think a couple of Japanese manufacturers demonstrated over at the DOT a few months ago two cars which they are now testing here which they said would withstand a 50-mile-per-hour crash. They were quite small cars. Are you working on that kind of thing and what does that do to the assumptions which are contained in your statement about safety?

Mr. TERRY. As fas as we know, the Japanese cars you refer to did not actually meet the requirements for the people to survive in the car. One of the problems with crash safety is that we have to provide crashability in the car in order to cushion the shock. This means that a front end which crashes like an accordion is actually very good as far as having the occupants of the car live through the crash. So making a car strong, and only making it strong, does not make it safe. It can actually make it less safe.

Mr. SYMINGTON. Where does the air bag fit into this picture? Or other forms of internal protection? This Japanese car was like a womb practically. I have never seen so much padding in my life.

Mr. TERRY. The passenger restraint system is probably the most important part of insuring occupant safety in a crash. The air bag system is an air cushion which pops out at the occupant after the crash has taken place. It cushions his shock if it is out in time and does its job the way it is intended. By cushioning the shock of the occupant meeting the interior of the car, the so-called second crash is greatly eased.

On the other hand, a superior restraint system would be one which instead of having the cushion jump out at the occupant would restrain the occupant in his seat. Such systems have been worked out. In fact, there is an inflatable belt system that one of the suppliers have done some development work on which looks like an ordinary lap and

shoulder belt—but in a crash of a given magnitude the belt system inflates very quickly and does not allow the driver or the occupant to move. In that respect it is a better restraint system than having something pop out of a car and try to cushion the occupant. Plus of course, it restrains in many other kinds of crashes also.

Mr. SYMINGTON. Can't we say at this point that the weight of the vehicle alone should not be depended upon for safety. Everybody knows that if a Cadillac hits a Volkswagen it is rather unfortunate for the Volkswagen. But isn't it reasonable to hope that at some point most cars can be small enough so that when they impact there is not a tremendous advantage of one over the other. Do you have any thoughts on that?

Mr. TERRY. Mr. Chairman, I certainly think we must aim for lighter and more efficient cars and that we can attain a greater degree of safety with lighter and more efficient cars.

However, there is no getting around the fact that with a given degree of safety in a car, assuming that you have done as well as you can possibly do with that car, if and you want to increase the degree of safety in the car in a crash, you are going to have to add weight. So the problem with regulations which circumscribe everything we do is that we have to make some undesirable tradeoffs many times to meet those regulations.

Mr. SYMINGTON. Mr. Downing.

Mr. DOWNING. Thank you Mr. Chairman.

I think you have made a very fine and interesting statement Mr. Terry. I take it you support the bill?

Mr. TERRY. Yes.

Mr. DOWNING. I have a great sympathy for the automobile industry. On the one hand, you are ordered to put all of these antipollution devices on your cars, and the same people order you to get better fuel economy. Somehow it seems strange to me that EPA has the authority to order better fuel economy. I'm glad they do but where does that authority come from?

Mr. TERRY. If I may say so, I do not believe that EPA has the authority to regulate fuel economy. In fact, I don't believe anyone has the authority to actually regulate fuel economy as of now. EPA now has what they call a voluntary fuel economy labeling program which they introduced for last year's cars, that is, 1974 cars, which most of the industry is working with. They are seeking to extend that voluntary labeling program with some additional information for next year's cars.

Mr. SYMINGTON. They are really trying to make more palatable their own stringent emission requirements by assisting in coping with the evolving problem of loss of fuel economy. Also, they have to try somehow to justify themselves to the public which is getting rather restless with the demands of the auto emissions systems and its effect on fuel economy. Isn't that part of the reason why they got into this thing saying they will look at fuel economy too?

Mr. TERRY. There could be many reasons why they got into it. But one thing I think the committee would be interested in knowing is that for next year's program they intend to introduce another figure for fuel economy which will be the results of measuring the fuel economy on about a 50-mile-per-hour average speed test. That figure

will look about 50 percent better as far as miles per gallon are concerned than the much lower figure resulting from the fuel economy measures during the EPA emission cycle test.

Mr. DOWNING. Have you been ordered to improve the fuel economy of your cars?

Mr. TERRY. We have not exactly been ordered. But we have been told it is very important and unless we do everything we can to improve the fuel economy somebody will pass a law. We have been told that several times. I would like to point out to the committee that it is very difficult for individual manufacturers—and the only way we can operate is as an individual manufacturer—to make any kind of commitment as to what we are going to do to improve fuel economy.

Our primary job, the Chrysler Corp. engineers, is to engineer cars we can sell to the public against the cars of our competitors. This means if we do something which improves fuel economy to our car but makes it run so that it won't get out of its own way at a traffic light, which is one alternative we have which will improve fuel economy, if we were to design such a car we wouldn't be able to sell it. So no matter how good our face might look in improving fuel economy, if we cannot sell them then you can forget all the rest.

Mr. DOWNING. Tell me something about unleaded gasoline and the effects on the automobile industry. Is there a requirement for the use of unleaded gasoline?

Mr. TERRY. There is a requirement put forth by EPA that requires gasoline stations which sell more than a certain number of gallons per month to carry unleaded gasoline and have it available for sale. The reason EPA came out with this requirement was because most of the automotive manufacturers have had to go—or have elected to go—to the use of catalytic converters in order to meet the strict emission standards required by the Federal interim standards for 1975 cars which are also put forth by EPA.

Interestingly enough when EPA put forth these Federal interim standards they put out two sets of numbers. One set they put out for the country as a whole expect for California. They said we ar this set of numbers such that we think the industry can meet that standard without catalytic converters. But we are going to have a more stringent set of numbers for the State of California that will require the use of converters in California. Thereby we will assure a gradual transition to catalysts because we will start in California and then it will be simpler to apply it to the rest of the country. At that time they foresaw the problems which might arise from going to catalysts and lead-free gas on a countrywide basis.

Unfortunately, EPA guessed wrong as far as the levels which could be met without catalysts in the rest of the country.

It now turns out that most of the manufacturers are going to have catalysts on most of their cars nationwide next year. This means lead-free gas will have to be available to service all of those cars. If a very much leaded gas is put into a car with a catalyst the catalyst gets damaged and some of the damage to the catalyst is permanent. So actually you will have to use lead-free gas in next year's cars if you want to maintain catalyst efficiency and maintain the low emissions the car is designed and built to achieve.

Mr. DOWNING. How much have all of these requirements increased costs? Do you have a figure on that?

Mr. TERRY. Yes, sir.

Up through 1974 cars the total cost of our safety improvements have been $344.

Mr. TERRY. The emission requirements were an additional $90 I believe.

For next year's cars the emissions requirements will catch up with the safety requirements as far as total cost is concerned because there will be another $200 approximately added to next years' cars for the catalyst systems. This will bring the emission total up to something like $290.

Mr. DOWNING. A total of $500 or $600?

Mr. TERRY. Well over $600 for next year's cars.

Mr. DOWNING. Is the day of the big car over?

Mr. TERRY. I don't believe so, Mr. Downing. As I indicated earlier, we will try to satisfy our customers as best we can as to size of cars, fuel economy, performance, and all of the other things going with it. I think that big cars will be less of a factor in the future. Because of the increasing importance of fuel economy, overall big cars I think will take less of the total pie. However, I still think there will be a substantial number of people in this country who will want the nice things which go with big cars for the foreseeable future.

Mr. DOWNING. Thank you very much.

Mr. SYMINGTON. Thank you.

Mr. Brown?

Mr. BROWN. Thank you, Mr. Chairman.

Mr. Terry, I would like to state initially that I have found your testimony to be extremely helpful. It is a very good statement. As a matter of fact, I was a little surprised that it went as far as it did in supporting this legislation, which I had expected to be opposed by the industry to some degree. I want to tell you that I am very pleased with what you have to say here.

Mr. TERRY. Thank you, sir.

Mr. BROWN. Your company of course has had extensive experience in working with NASA, if I am not mistaken?

Mr. TERRY. Yes, sir.

Mr. BROWN. It was a major contractor in the space field, and you are accustomed to a working relationship with NASA which allows you, as a private company, to do the things you can do best and NASA to do the things they can do best. I presume you have had some differences and disagreements. But overall I would gather that the relationship has worked out satisfactorily; is that true?

Mr. TERRY. Yes, sir.

We have a fine record, we feel, working on the space program starting with Redstone and going all the way up today, we have worked with NASA on various kinds of space and defense programs.

Mr. BROWN. Is your company, amongst the Big Four automobile companies, predominant in working with NASA? That is, does the contracts your company has had exceed those of the other companies?

Mr. TERRY. I cannot answer that for sure, but I would be happy to submit a statement. I really do not know the magnitudes of the programs of our competitors within the space program.

Mr. BROWN. I don't have the figures either, but I thought maybe this was common knowledge within the industry.

Mr. TERRY. No.

Mr. BROWN. Of course, it is only realistic to recognize that dealing with the space program you have one kind of an animal in which the market is the government and in dealing with commercial transportation you have another kind of animal in which the public is the customer. And the working relationships, insofar as NASA is involved would have to be scrutinized much more carefully. I think that is a safe statement to make. We have had other witnesses who have testified to the value of the research work done in the NASA laboratories. You mentioned Lewis, I believe?

Mr. TERRY. Yes.

Mr. BROWN. And other witnesses—I recall one from a small company developing steam power for automobiles—testified that the work of Lewis either had been or could be of extreme value to them in development of materials which would resist higher temperatures and pressures and so forth.

Could you offer to the committee some suggestions as to the proper spheres of Government research, and private development and production, could be delineated so that we would not run into this criticism that Government is infringing upon the prerogatives of private industry or vice versa.

Mr. TERRY. Of course, that is difficult to do but they are doing quite a bit of work now that we feel would be helpful to us, as we pointed out in the testimony, on things like blade-shape for better flow through turbines. We mentioned improved materials. If we can increase the operating temperature inside the turbine we can improve the fuel economy significantly for each 100° we can increase the temperature. So anything that can be used in devleoping materials would be helpful.

Mr. BROWN. Obviously this is the sort of thing that the scientists and laboratories of NASA have worked on which could be a very great benefit. We cannot spell out legislation that they will just work on turbine blades, but we have to establish some general guidelines which will reassure the industry and the public and the Members of Congress particularly. Very frnakly, I think that the industry is the party most concerned and it ought to have a significant voice in determining just where NASA could be helpful and where they would be infringing.

Mr. TERRY. Mr. Huebner would like to say something about that. But before he does, I would like to say that as far as we are concerned at Chrysler, I do not think anyone will be stepping on our toes or infringing on our rights or prerogatives if they come up with a better engine which is nonpolluting, clean, and all the rest. We want to see the problem solved. We certainly are not going to take a position that we are against anyone else working on the problem. We need all the help we can get. Our work and successful cooperative ventures with NASA in the defense area is such—I have read the testimony that they gave before your committee a month ago——

Mr. BROWN. In February.

Mr. TERRY. We agree with the approach they will take the way we feel about it is we work it out as we go along because they won't go into some backroom and start to work on research while we are in

some backroom working on research. We will talk to each other about what we are doing and do it in a cooperative sense.

Mr. BROWN. I think your good relationship with NASA has given you a confidence which perhaps is not shared by those who do not understand the pattern your company has developed with NASA over the years. To take an extreme example, there might be some people who would fear that giving NASA an authorization to work on ground propulsion systems might mean that they would be out with a production line producing motors. Obviously, we do not want that to happen, yet we do want them to be able to develop sub-systems or maybe even prototype engines which could demonstrate whether or not they have got the problem solved.

Mr. TERRY. Yes, sir. I think we have an example of this in our testimony today too—your Honda has this thing all solved. They have an engine they will use which is lower in pollution and so on. We say OK, we will work with Honda. We made an agreement and got the engine. They don't have the problem solved at all for us, but they have taken some important steps. So we are trying to see if we can work with Honda and take what they have done and apply it to our size engines for our cars and make something out of it. We have a cooperative arrangement with Honda. They did a lot of work. First, they went so far as to build an engine. If NASA builds an engine that gets low-pollution and so on and they say OK here is an engine with these characteristics, fine, we would welcome such an opportunity to work on it and see if we could apply it and develop it further.

Mr. BROWN. I didn't mean to cut off Mr. Huebner.

Mr. HUEBNER. Mr. Brown, I believe my personal friendship with NASA goes back to the beginning of World War II. When the Lewis research labs were built I was a member of a committee at that time which reviewed what they were doing, how they were doing it, their approaches to the powerplant problem, and so on.

Now aircraft powerplants and automotive powerplants are fundamentally the same type of powerplants. They are fuel-burning engines and heat engines. And the same principles are involved in the automotive field as they are in the aircraft field. There are great differences in the requirements of the powerplants. There are great differences in the way things have to be done. But nevertheless, the principles remain the same. And over the years, particularly at the Lewis laboratories which I am most familiar with, although I am familiar with the rest of them, starting with NACA and then NASA, the Lewis laboratories have developed a pattern of cooperation which is largely what the statement talked about. In other words the application of scientific principles to advance the understanding of the state of the art. This has been very productive. It has been particularly productive in the aircraft industry and in aircraft powerplants. We do build the best aircraft powerplants in the world. There is no question about it. Much of that is due to the pattern of operation which was worked out with the Lewis laboratories.

Now, they do not build powerplants themselves, but they show the way it can be done.

Mr. BROWN. To our knowledge, has there ever been any major problems, as far as Lewis and the aircraft industry is concerned, about their roles in developing the best aircraft engine in the world?

Mr. HUEBNER. Not to my knowledge, and we were in the aircraft engine business too for many years. Not to my knowledge has that subject ever been really discussed.

Mr. BROWN. Let me go into a couple of other points—I do not want to take too much of your time. Let me go back to the question the chairman raised earlier having to do with the level of your expenditures in various aspects of research with regard to engines. I am not going to ask you to provide information, but in our February hearings we elicited comparative information which is shown on page 103, of the hearings dealing with the resources expended for emission control, alternative powerplant research, etc.—I think you have the document before you. You mention, for example, a figure of $3.9 million for 1973 whereas the table shows 3.5 which might merely reflect that you increased your level of expenditures?

Mr. TERRY. That is right. That was an estimate and now we have the final figures.

Mr. BROWN. Right. I would like to ask if you could provide for the committee an updating of all of the figures given in this table and if it is possible if you could indicate any projections you would have for the next year or two as to the amount your company will be expending in these various categories.

Mr. TERRY. We will be glad to do that.

[Above requested information will be available from committee files.]

Mr. BROWN. I think all of the members are concerned about the problem created by NO_x standards. Of course, it is apparent that there will be some efforts to adjust these standards perhaps during this year to a figure which you describe as more realistic.

You suggest that the 2-gram-per-mile standard would solve a lot of your problems. I wanted to raise the question as to whether or not a 1-gram-per-mile standard, which would represent a substantial easing of the standards, would make a major difference, or do you feel that 2 is the magic number here?

Mr. TERRY. Mr. Brown, when we get down to two we have already sacrificed some possible efficiencies which we do not know how to get back. When we go below two, the sacrifices get to be very painful.

Mr. BROWN. There must be some sort of a curve.

Mr. TERRY. There is.

Mr. HUEBNER. Let me quote something you will find rather shocking. We talked about the TCCS engine here. About 7 months ago at an EPA powerplant conference in Ann Arbor, Mich., which is held there twice a year, the army, which is also working with the TCCS engine testified that in order for them to meet the 4/10 number they had to depreciate the basic fuel economy of a TCCS engine 34 percent.

To depreciate it from its base fuel economy as an uncontrolled engine to about 2 grams per mile, you would still have a 25-percent improvement over the piston engine. But if you are going to go down to one, it might drop off to a 10 or 12 percent advantage over the ordinary spark ignition piston engine.

So the sacrifice from 10 to 25 is almost another 25 percent in order to go from two to one.

Mr. BROWN. I can see the nature of the problem. We will probably have submitted to us a lot of information dealing with the relative

penalties associated with it. It ultimately gets down to political judgment I guess on the part of the Congress as to where they will set it.

Mr. Terry, I am intrigued by your position as vice president for public responsibility and consumer affairs. Is that a recent position created in the corporation or is it of long standing?

Mr. Terry. It is not a recent position. I reported to a vice president with that title, Mr. Byron Nichols and I had the title of vice president of safety and environmental relations. Mr. Nichols is retiring so I took over his title and responsibilities with some additional personnel and offices. I am still carrying on what I was doing before.

Mr. Brown. I am sure you are aware that the automotive industry as a whole receives a good deal of criticism, which you may feel is in large part unjustified, for its failure to solve some of these pressing national problems. You have been blamed for both the environmental condition of the country and for the fuel crisis and a lot of other things. Your burden will become very heavy, I think.

Mr. Terry. Congressman Brown, I was hoping that it wouldn't get any heavier. I can't think of any ill we have in this country that automobiles don't seem to be blamed for. Hurriedly looking over yesterday's testimony, the industry seemed to be painted in a bad light. Also with statements which could not possibly be backed up or proven because they are just not true. I wonder why somebody from the committee and other places in Congress doesn't some day stand up and ask some of these critics how they can justify some of these statements which are made.

Mr. Symington. Would you be good enough to mark those and submit for the record the unsubstantiated statements? We do not have a great deal of time to pursue this at this time.

Mr. Brown. I understand, Mr. Chairman.

Mr. Symington. I am very hopeful we can do that.

Mr. Brown. We would like to have that information, Mr. Terry. I can tell you that I have been guilty of some of these criticisms myself and I will continue to be critical of the industry, just as I expect you to be critical of Congress. But I think the real problem is that we have different definitions of public responsibility. This is why I focused on your title. There are those who claim that the automobile and its repercussions in our society is the root of all evils. You might be interested in reading a very recent book by Ivan Illich, entitled "Energy and Equity," which deals with the subject. He is a noted critic and philosopher. He first aimed his criticism at the church and the school system and now he is analyzing the automobile industry.

Mr. Terry. Wait until he gets to Congress. [Laughter.]

Mr. Symington. There are some things that are really too sacred. [Laughter.]

Mr. Brown. He does suggest very strongly, Mr. Terry, that we would be better off if we went back to a bicycle. There is a good deal of support for that in the country today.

Mr. Symington. People like Schwinn? [Laughter.]

Mr. Milford?

Mr. Milford. Would you be willing to let me submit some questions to you by mail to be included in the record?

Mr. Terry. Yes.

Mr. Milford. I ask unanimous consent they be inserted in the record.

Mr. Symington. It is so ordered.

CHRYSLER, INC.,
June 28, 1974.

Mr. FRANK R. HAMMILL, Jr.,
Counsel, Committee on Science and Astronautics, House of Representatives, Suite 2321, Rayburn House Office Building, Washington, D.C.

DEAR MR. HAMMILL: This is in response to your recent letter of June 17 requesting answers to the additional questions submitted by Congressman Brown of California.

In response to questions 1 and 2, the enclosed attachment updates Chrysler Corporation's report on the dollar resources and professional technical man years for emission control for the calendar years 1970 through 1974.

Question 3.—We do not have specific mileage goals for each vehicle we market. Because of the stringency of the emissions control standards our first objective must be to make our engines meet those requirements. After we have developed the basic emissions systems to meet those requirements, we then engineer the best fuel economy we can into each vehicle-engine combination. As I indicated in my prepared testimony "it is unfortunately true that these two objectives (reducing undesirable exhaust emission and improved engine efficiency) are sometimes counter to each other by natural laws which we can only try to circumvent but which we cannot change."

Question 4.—When we design a new model we establish weight targets for the vehicle. We carefully track the weight of the vehicle through its design and development program to make sure we are on target. During this development period we also periodically consider whether there are any major changes that could be made to substantially reduce its weight. In addition, of course, our engineers continuously look at the components in all of our models with the view toward reducing the weight of individual parts and assemblies by substitution of lighter materials, product simplification, and other changes.

Question 5.—One of the major restraints on future development of stratified charge engines is the stringency of future emission control requirements, especially the NO_x requirements.

As Mr. Huebner and I indicated in our testimony the more stringent the control of NO_x required, the more drastically it depreciates the basic fuel economy of these engines. The very stringent controls currently required by law for 1977 and later model engines constitutes a major deterrent to further development of stratified charge engines since their fuel economy at that control level would be very poor. In addition, as I indicated in my testimony, the stratified charge principle has not yet been adapted to larger engines for U.S. size cars. Trying to apply the stratified principle to larger engines requires a delicate and time-consuming development process.

Question 6.—As indicated in the answer to question 5 the currently specified stringent NO_x control requirement is a major restraint on the development of all the alternative engine technologies discussed in our statement. Consequently, we do not foresee production of new alternate power plants in the near future if the schedule of emission requirements remain at the levels specified by the current law.

Assuming the technology of an alternative power plant was completely developed and that it would meet the updated emissions requirements successfully, we estimate that a minimum of three years would be required for tooling, arrangement of manufacturing facilities, etc. to phase it in for a portion of our production. At least eight years would be required to convert our total production to a new power plant after the technological development is completed.

As I indicated in my testimony we believe the alternative power plant that shows the most promise of meeting passenger car power plant objectives in a way which gives it substantial advantage over all other power plants used today is the automotive gas turbine.

Question 7.—We cannot speak for the total U.S. auto industry but Chrysler Corporation continues to market the internal combustion engine in our cars because we believe it is the best available engine for U.S. sized cars and U.S. motoring conditions. In our opinion, there is still no alternative power plant for U.S. size cars and driving conditions that can compete successfully on a cost/performance basis for any given emission control level. As I indicated in my testimony, because of their smaller production volumes some foreign car manufacturers may find it profitable to manufacture cars with other power

plants and special features which a very few buyers find extremely attractive in order to try to increase their sales of cars in the U.S. and other markets.

Also attached is my critique of some of the testimony given before the Science and Astronautics Committee, U.S. House of Representatives, on June 11, 1974 which was requested by Congressman Brown, as noted on page 327 of the transcript as submitted to me.

We hope the above answers to Congressman Brown's questions will assist the committee in its deliberations. If you have any further questions we will be glad to try to answer them.

Sincerely,

S. L. Terry,
Vice President, Public Responsibility and Consumer Affairs.

CHRYSLER CORPORATION

EMISSION CONTROL
DOLLAR RESOURCES AND PROFESSIONAL TECHNICAL MAN-YEARS
CALENDAR YEAR 1970, 1971, 1972, 1973, 1974
(Dollars in Millions)

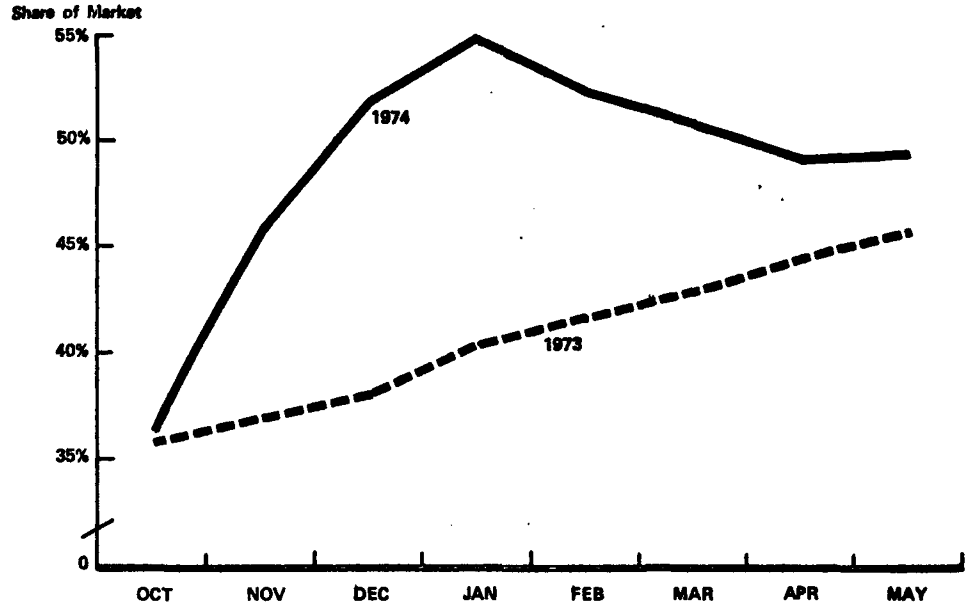
	1970 Actual		1971 Actual		1972 Actual		1973 Actual		1974 Forecast	
	Dollar Resources	Professional Technical Man-Years	Dollar Resources	Professional Technical Man-Years	Dollar Resources	Professional Technical Man-Years	Dollar Resources	Professional Technial Man-Years	Dollar Resources	Professional Technical Man-Years
Engine Modification	$ 3.7	166	$ 4.2	170	$ 5.3	233	$ 9.6	362	$14.6	500
Elect. Eng. Control	.4	12	1.0	38	1.1	48	1.7	64	1.9	70
Thermal Reactors	1.9	79	3.0	101	1.9	84	2.3	87	2.4	90
Catalytic Reactors	1.4	70	3.5	114	7.0	305	14.1	532	14.3	490
Alternative Prop. Sys.	.1	2	.3	11	0.8	35	4.4	166	2.8	100
Total	$ 7.5	329	$12.0	434	$16.1	705	$32.1	1211	$36.0	1250
Administrative Support	$ 1.2		$ 1.4		$ 2.5		$ 2.8		$ 3.0	
Total	$ 8.7		$13.4		$18.6		$34.9		$39.0	
Capital Expenditures	$ .3		$ 1.0		$ 1.2		$17.0		$11.0	
Total Resources	$ 9.0		$14.4		$19.8		$51.9		$50.0	

Note: These figures have been prepared by using analysis techniques and are not taken from official books of record.

Chart 2

SMALL CAR* SHARE OF TOTAL INDUSTRY

1974 --VS-- 1973 MODEL YEAR



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
1974 MODEL YEAR	36.4	45.9	52.0	55.0	52.5	50.8	49.3	49.5
1973 MODEL YEAR	35.8	37.0	38.2	40.5	41.8	43.1	44.6	45.7

* Small cars include Foreign, Domestic Sub-Compact, Compact Standard and Compact Specialty entries.

CRITIQUE OF TESTIMONY GIVEN BEFORE THE SCIENCE AND ASTRONAUTICS COMMITTEE, U. S. HOUSE OF REPRESENTATIVES, ON JUNE 11, 1974

Statement of Congressman George E. Brown, Jr.

1. Mr. Brown: I am somewhat concerned that administrative questions will obscure the facts that the existing ground transportation system in the United States is near collapse.

   Comment: The existing ground transportation system in the United States is without any question the finest transportation system in the world. There is no substitute for transportation which enables a person to move from his home (or wherever he is) to where he wants to go without having to interface with other various transportation modes. Studies on the cost per passenger mile on various kinds of transportation provided by HUFSAM bear this out.

2. Mr. Brown: This [ground transportation] system is based upon the private automobile, which itself is based upon the energy-consuming and pollution plagued internal combustion engine.

   Comment: So-called pollution from the present internal combustion engine has been reduced by over 70%. The air is getting cleaner all the time.

3. Mr. Brown: There is a considerable body of thought, which I share, that says the existing structure of the automobile industry is so highly concentrated and anti-competitive that it is capable of preventing changes in our ground transportation system that are perceived as detrimental to the automobile industry.

Comment: Far from being able to prevent changes, the automotive industry is today so subject to regulations from so many quarters that there is real danger in having regulations conflict to the point where automobiles can no longer be built to meet all regulations.

4. Mr. Brown: Even if this is not the case, there is serious doubt that voluntary efforts by the automobile industry alone to convert to an alternative technology would succeed, even if such a decision to convert was made.

Comment: The automobile industry cannot do anything cooperatively; but, as a competitive matter, when and if a superior powerplant is demonstrated, the first company to convert will benefit greatly. If the advantages are sufficient as far as the public is concerned, the rest of the industry will have to follow.

5. Mr. Brown: The effects of emissions was known in the early 1950's, but genuine progress in controlling auto emissions did not occur until after passage of the Clean Air Act Amendments of 1970.

Comment: By the time the Clean Air Act of 1970 passed, over 60% of the emissions of HC and CO had already been eliminated from cars built in California and future standards had been set by that state that would have accomplished reductions approximately up to the levels obtained in our 1974 cars.

6. Mr. Brown: The progress under that law has now come to a halt because the Congress amended the law this year to freeze the standards for two years, beginning this Fall.

   Comment: The 1975-76 standards are not "frozen" for two years but actually constitute levels less than half the 1974 levels for hydrocarbons and carbon monoxide, and the levels of oxides of nitrogen are being reduced 35% in 1976.

7. Mr. Brown: Instead they [automobile industry] had to be forced to clean up their machines and they may have to be forced to develop efficient machines.

   Comment: When it comes to anti-pollution devices, performance regulations are required since low-pollution cars cannot be sold for a premium price to the public against cheaper but higher pollution cars.

8. Mr. Brown: The impact of the automobile upon the American economy is too pervasive and too important to trust the future of our Nation to the decisions made in Detroit.

   Comment: The decisions are being made in Washington as to the performance levels required. Detroit should and will make the decisions necessary to reach those levels at the lowest possible cost to the consumer.

Statement of Congressman Charles A. Vanik

1. Mr. Vanik: Today, hydrogen can generally only be obtained by the expenditure of a large amount of energy. But in the near future, I believe that the use of solar energy, including the use of thermal gradients in the oceans, and fusion energy can make a hydrogen fuel society possible. We should prepare now to know how to use pollution-free hydrogen in our ground propulsion systems.

   Comment: The very recent letter from D.O.T. with the questions regarding the safety of our 1975 emission control systems will be of interest to anyone who is considering the advisability of hydrogen fuel as well as any other kind of alternate fuel. (Tr. 231, line 22)

2. Mr. Vanik: EPA, Treasury, and the Department of Transportation all came up with potential fuel savings of 1.4 to 2.0 million barrels of gasoline per day within a few years if existing technology was applied to auto manufacture.

   Comment: When reviewing the existing technology to save fuel of cars, tradeoffs in safety, emissions and comfort features must be considered. Building good fuel economy cars that have poor performance, no air conditioning, no power steering may be feasible but, if the cars cannot be sold to the customer in competition with more efficient and desirable vehicles, it will not result in any overall fuel economy for the country. (Tr. 233, lines 18-25)

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3. Mr. Vanik: A NASA study could show how our autos could be made more efficient--and would put an end to the endless attempts to blame poor mileage on EPA Clean Air regulations.

   Comment: Other things being equal, lowering limits for oxides of nitrogen is going to result in the loss of fuel eco·.my. (Tr. 234, lines 2-5)

Statements of Carl E. Nash and Clarence M. Ditlow

1. Messrs. Nas' and Ditlow: Since the 1930's, the only important innovations that have been incorporated into new cars are air bags for occupant crash protection, catalytic type exhaust emission converters, and stratified charge piston engines.

   Comment: We are attaching a list of innovations in safety areas and other areas that have been made since the 1930's in our automobiles. The witness here is talking about improvements that have been talked about in the press but have not yet been fu ly developed. (Tr.250, lines 7-10)

2. Messrs. Nash and Ditlow: The first of these was introduced on a very limited basis this year by General Motors, and the second will be found on most domestic cars to be marketed this fall. The third will be found only on the Japanese Honda Civic next year.

   Comment: See our testimony on the Japanese Honda stratified charge engine. (Tr.250, lines 13, 14)

3. Messrs. Nash and Ditlow: In 1973, for example, Chrysler spent $400 million on tooling and equipment for the redesign of its full size car lines, cars that have since become a glut on the market.

Comment: Annual model changes are required in order to accomplish quality improvements to meet safety and emission regulations and to reduce cost. In a volume production industry, the most efficient and sometimes the only way to accomplish important changes is to empty the pipelines and stop production, then refill them with new parts and start again with the new model. Retooling is often necessary anyway. Thus, if a large number of changes can be made at one time, it may pay in cost savings and permit appearance to be altered for marketing purposes essentially at no extra cost to the company or the consumer. (Tr.252, lines 9-15)

4. Messrs. Nash and Ditlow: Bradford Snell has estimated that due to the annual style change and the need to produce around 300,000 similar vehicles to achieve economies of scale, the investment needed to enter the domestic auto market is $779 million of which $724 million would be needed to provide annual style change capability.

Comment: Unsubstantiated, unprovable hogwash. Certain kinds of cars actually sell better without annual styling changes, e.g.

Volkswagen. Domestic manufacturers would love to be able to sell cars with minimal changes from year to year. (Tr.252, lines 18-23)

5. Messrs. Nash and Ditlow: Much of this work, such as on the Wankel engine, stratified charge engine, turbines, and Stirling engine is based on old or borrowed technology, sometimes paid for at a cost in excess of the probable cost of original research and development work.

Comment: There is no magic answer to the powerplant problem any more than there is a carburetor that will get 50 miles per gallon. It is relatively easy for the experienced engineer to rule out the great majority of alternate powerplants from mass use in automobiles on the basis of cost or performance or loss of fuel efficiency or lack of suitability for powering an automobile, or some combination of these. Even with the millions of dollars that have been spent to develop a gas turbine, the best we have to offer still does not come close to matching the internal combustion engine with all its faults when all of the features are considered, especially that of manufacturing cost. If NASA, EPA, or anyone else can show us a better engine considering all these factors, we will be glad to build it. (Tr. 253, lines 14-18)

6. **Messrs. Nash and Ditlow:** The evidence brought together prior to this suit by a Los Angeles Grand Jury outlined the cross licensing agreement and other close associations between these so-called auto competitors that forged this illegal, united front of inaction.

Comment: The cross-licensing agreement was approved by the Federal government and very much encouraged by the State of California because of the belief that air pollution research would progress more rapidly under such an agreement than without it. No decision was ever made that there was anything illegal about this cross-licensing agreement, and far from holding up progress in controlling emissions, it actually speeded it up under the conditions prevailing at that time. (Tr.254, lines 23-25, Tr.255, line 1)

7. **Messrs. Nash and Ditlow:** According to an Environmental Protection Agency memorandum, the automotive air pollution resulting from this conspiracy cost the American government $2.7 billion. The cost to the American public was even higher.

Comment: We would like to see reference 8. We have never seen any proof of any substantial cost to the American government or American public due to automotive air pollution. We have EPA documents to bear this out. (Tr.255, lines 8-11)

8. Messrs. Nash and Ditlow: If the domestic auto industry had converted to the stratified charge engine, the consumer would have saved $120.60 for the emission controls on 1974 cars according to the National Academy of Sciences and at the same time would have enjoyed 12 percent better fuel economy according to the EPA.

Comment: We have been working with the Honda engine for better than a year now, and our experience thus far does not support these statements. See our testimony. (Tr.256, lines 13-18)

9. Messrs. Nash and Ditlow: It seems incongruous that the federal government should have to subsidize research and development work that will probably be in the self-interest of this multi-billion dollar corporation. By comparison, GM and Ford participated in the Department of Transportation's experimental safety vehicle program on a one-dollar contract basis.

Comment: While lower emissions and better fuel economy are possible with future turbine designs underway, turbine cost is still an outstanding barrier to actually producing this powerplant in volume. Even should the cost problems be somehow overcome by manufacturing development, a reachable oxides of nitrogen standard would have to be specified for a long enough period of time to enable a tremendous investment that will be required to produce turbines in volume to be amortized

and thereby justified. So far there have been no such assurances or even any intimation that such assurance will ever be forthcoming. (Tr.257, lines 14-16)

10. Messrs. Nash and Ditlow: Small research and development companies such as Steam Power Systems, about which you heard on February 6, 1974, and entrepreneurs like William Lear and the Carter family from whom you will hear on June 18, may, without the historical encumbrances of the auto makers and traditional automotive engineering, be able to make the breakthroughs necessary to achieve the revolutionary design changes that will be necessary for the continued co-existence of man and his transportation systems.

    Comment: Not one single alternate powerplant proposal has proved to have any substance including Lear, Carter, SPS, and all the rest. The day that one looks like it actually has potential, Chrysler for one hopes to be the first to take advantage of it. The Honda appeared to have such an advantage; now it looks doubtful, as described in our testimony. (Tr.257, lines 22-25)

Statement of Robert F. Sawyer

1. Mr. Sawyer: I am personally uncomfortable that these expenses are being invested in a technology which is less than the optimum and the most cost-effective and that the federally mandated controls have been specified from a very shallow technological base.

Comment: We are completely confident that the emission controls in automobiles so far have been as cost-benefit effective as possible under the pressure of artificial deadlines and low levels set by the 1970 Clean Air Act. There are no present known solutions so there has been a great deal of inefficiency due to inability to meet the levels in the specified time. This inefficiency will continue to cost the American public billions of dollars until a more realistic, scientific approach is taken and costs are considered along with benefits that can be attributed to further reductions in automotive emissions. In our opinion the 1975 automobiles will be a big step beyond the point of diminishing returns as far as automotive emission control is concerned. (Tr.268, lines 1-6)

2. Mr. Sawyer: With the energy crisis and resulting long overdue concern with the poor fuel economy of the American automobile, an unfortunate misconception exists that improvement in automotive fuel economy, emissions, and performance cannot be pursued simultaneously--that improvement in one characteristic must necessarily be at the expense of the others.

Comment: We have always made it clear that control of hydrocarbons and carbon monoxide can be accompanied by better fuel consumption, and the initial engine modification approach pioneered by Chrysler demonstrated this fact. On the other hand,

the more recent required control of oxides of nitrogen does inherently penalize fuel consumption. Originally, even the California authorities felt that NO_x control was not necessary if hydrocarbons were controlled. (Tr.269, lines 9-14)

Mr. Sawyer: Unfortunately it is the foreign automobile industry which is leading the way in bringing advanced technology to the production state. I am disappointed that we must go to foreign manufacturers in order to be able to purchase economical cars with fuel injection, electronic controls, automated diagnostic equipment, Diesel engines, non-catalyst based emission control systems, and, soon, the first of the stratified charge engines. I am similarly dissatisfied with the U.S. automotive industry for giving 15 percent of the U.S. car market in 1973 to foreign manufacturers (17 percent in January of this year), apparently because of a decision to emphasize production and marketing of large, inefficient automobiles.

Comment: None of the features listed were pioneered by foreign cars, but most have been provided in foreign cars for sale to the U.S. for their novelty value. Such features can be sold at a premium when volume sales are low, and such is the case with the equipment on the foreign cars mentioned. When and if any of these features provide suitable cost benefits, they will be put into production on U.S. cars. Our electronic ignition system is a sample of such a device, which we have had for two

years in all of our cars and which we provide for very low cost compared to the foreign versions. (Tr.270, lines 18-25; Tr.271, lines 10-13)

Statement of Congressman Symington

Mr. Symington: But aren't you saying that if they retooled for a smaller car, considering the effect of added weight on the efficiency of the car . . . that it would still be within the general and expectable range of cost to the consumer. (Tr.279)

Comment: Attached is a chart showing that the small car penetration of the total market is increasing with the result that the public is benefiting from lower initial costs and fuel economy.

Mr. MILFORD. If you think your industry has troubles then try the oil industry.

Mr. SYMINGTON. Thank you, Mr. Milford.

We will let you begin the questioning of the next witness.

I thank you gentlemen very, very much for your appearance today and for your help to us.

The next witness is Mr. Don Jensen, director of the Automotive Emissions Office of the Ford Motor Co. Mr. Jensen has been with the Ford Motor Co. since 1966 and he previously served with the California State government in the field of emission controls.

[A biographical sketch of Mr. Jensen follows:]

DONALD A. JENSEN

Donald A. Jensen was appointed Director of Automotive Emissions, Environmental and Safety Engineering Staff, Ford Motor Company, in January 1969. He represents Ford with Federal and State governmental agencies charged with enforcement of vehicle emissions and noise control requirements, and coordinates the Company's motor vehicle emission control, fuel economy, and noise control planning.

Mr. Jensen joined Ford in April 1966, as Executive Engineer, Vehicle Emissions and Regulations Office, following a career as a government administrator.

He was the first Executive Officer of the former California Motor Vehicle Pollution Control Board and played a key role in the state's efforts to establish emission controls on all automobiles sold in California, two years prior to similar action nationwide.

Mr. Jensen is Chairman of the Air Quality Committee of the Motor Vehicle Manufacturers Association, and is a past President of the Air Pollution Control Association. He also is a member of the Society of Automotive Engineers.

A native of San Francisco, Mr. Jensen was born August 5, 1915. He holds Bachelor's and Master's degrees from the University of California. While an undergraduate, he was a member of the 1936 United States Olympic Basketball Team.

He lives in Dearborn Heights, Michigan.

STATEMENT OF DONALD A. JENSEN, DIRECTOR, AUTOMOTIVE EMISSIONS OFFICE

Mr. JENSEN. Mr. Chairman and members of the committee, my name is Donald A. Jensen and I am director of the Office of Automotive Emissions of Ford Motor Co. I appreciate your invitation to appear before you to discuss H.R. 10392 and the general subject of research and development of ground propulsion systems, specifically automotive engines.

The bill under consideration would give the National Aeronautics and Space Administration authority to develop new alternate ground propulsion systems and to conduct research in alternate energy sources for use in such systems. It is our understanding, and the hearings of this committee support these facts, that the Environmental Protection Agency, Department of Transportation, Department of Defense, NASA, Atomic Energy Commission, the Postal Service, and the National Science Foundation all have active programs in some aspect of new alternate ground propulsion system development.

There is, however, at present a basic division of responsibility between EPA with assigned research leadership for alternate power source development for private transportation and the Department of Transportation who has responsibility for public mass transit and total transportation systems. Published reports also indicate that the major

American automobile manufacturers are involved actively in research and development of alternate power sources. Congress may want to play a major role in establishing priorities, not only in respect to Government versus private funding, but also in respect to conflicting values such as emissions versus fuel economy or vehicle damageability versus fuel economy. This could avoid wasteful deplication of effort.

In addition to our in-house work, Ford, in November 1973, made an independent grant of $500,000 to the Jet Propulsion Laboratory in Pasadena, Calif., to conduct a comprehensive study of this entire field of alternate power sources. A copy of the statement of objectives for that study is attached for your information and I would like to ask that it would be put in the record, Mr. Chairman, since it bears directly on the subject of this hearing.

Mr. SYMINGTON. It is so ordered.

[The document referred to above is as follows:]

STATEMENT OF OBJECTIVES FOR FORD GRANT TO JET PROPULSION LABORATORY, NOVEMBER 1973, FOR AUTOMOBILE POWER SYSTEMS EVALUATION STUDY

The purpose of this study is to provide independent research studies and technical appraisals of potentially promising alternatives to the internal combustion engine.

The overall objective of these evaluations is to provide independent, objective guidelines for achieving and maintaining optimum vehicle characteristics with respect to national needs and desires for clean air, conservation of non-renewable natural resources, improved safety and general betterment of mobility and quality of life within an affordable economic framework.

A concomitant general objective of the evaluations is the proper timing of actions relating to power system changes—the research and development lead-times for various propulsion alternatives, time-phasing of logistical support and infrastructure development, feasible rate schedules for large-scale conversion to alternative systems, etc. In other words, the overriding questions relate not to what can be done, but to what should be done and when in order to gain significant advantages over today's internal combustion engine and its logical and likely evolutionary derivatives. It is expected that comparisons of all alternatives will be made against a moving baseline of timely improvements and extensions of present engine technology. For all comparisons, the time-frame of greatest interest is the decade 1980–1990, but study attention must extend well beyond this period to comprehend such things as resource availabilities including potential for different fuels; full-conversion evaluations and economic implications.

Specific objectives with respect to each admissible alternative course of action would include the following:

A. An engineering appraisal, including identification of operation characteristics and parameters, of major unresolved technical considerations, including time and cost estimates for their probable resolution.

B. A determination of the earliest feasible and practicable large-scale conversion of vehicles to the system, with an estimate of the most reasonable conversion rate.

C. An assessment of the probable total aggregate economic, natural resource, environmental and societal impacts of the conversion, including production, logistic and energy support requirements. Here, explicit attention should be directed to forecasting future motor vehicle use and limits or boundaries thereto, taking into account changed land use policies, new life styles and the probable increased availability of public transportation.

D. An overall comparative evaluation in relation to forecasted internal combustion engine technology, including the engine improvement information that has been provided to the National Academy of Sciences.

E. Explicit development of manufacturing costs for major system components, treating them parametrically where costing uncertainties so dictate. Here, extensive use of sensitivity testing would be indicated to define cost targets critical to decision choices.

F. Categorization of research and development requirements into tasks that logically call for either government funding or industry funding, depending on the size of commitment, time for payback, recipient of the benefits, probability of success, etc.

During the course of this effort, Ford will make available information on present internal combustion engine technology to the extent that such information would not be prejudicial to any patent or proprietary interest. Ford will also make available alternate engine information such as that already provided to the Environmental Protection Agency and the National Academy of Sciences. Ford's parallel efforts to forecast technology and socioeconomic and environmental factors will *not* be made available in order to avoid introducing an appearance of bias or lack of objectivity in the study.

For example, one portion of that study calls for JPL's recommendations on funding by either the Government or industry depending on the size of the commitment, recipient of the benefits and other factors. I want to stress the independence of this study. We purposely did not ask for progress reports because we felt to do so would imply that we were guiding the direction of the Jet Propulsion Laboratory study. When the project is complete next January, its findings shall be made public so it can be utilized by Congress, Government agencies and private industry—hopefully as a guide toward future research and development of ground propulsion systems as contemplated in this bill.

In its own laboratories, Ford has directed an aggressive program toward the improvement of today's conventional engines, the modification of current engines to incorporate advance technology such as prechamber or stratified charge designs, and the developments of alternate power sources.

We have good reason to design and produce new engines with low emissions, good fuel economy and performance, and all of them at a lower price than our competitors can. Such an achievement would give us a tremendous advantage in the marketplace. Automobile manufacturers constantly compete to develop the most cost-effective, low-emission new engine.

I would like to address my comments, first to the present status of engine design as it relates to emission standards, fuel economy, and cost. Second, I would like to report on the progress of Ford's short- and long-range programs for engine development. Finally, I would like to comment on how we believe the Government can contribute best to further technological and cost-effective advancement in the field of ground propulsion.

For the past 8 years, Ford has directed a major part of its engine design effort toward developing exhaust emission controls for today's conventional engines. We now produce 13 different major engine families and the technology we developed had to be applicable to each of these different engine families. We have faced and met new emission standards almost every year since 1966. This has been done primarily by adding emission control components and by making design changes to the engines which unfortunately usually raised the retail cost of the vehicle and depreciated the fuel economy. As a result, the average 1974 model Ford car costs $80 more than the 1967 model uncontrolled vehicle and achieves approximately 10 percent less fuel economy. Because of the need for incorporating catalysts to meet the 1975 interim standards, the 1975 customer cost penalty will be about $175 over the 1974 model. We are not yet certain about fuel economy of our 1975

models, but believe there will be an improvement due to the usage of catalyst technology.

While our production vehicle engineers work in this area, our advance and research group have engaged in major engine designs. We have shared our development results with EPA and with appropriate subcommittees of the National Academy of Sciences who are reviewing the current status of such efforts under terms of a congressional contract. Major improvements applicable to today's engines that are under development at Ford include: Advanced carburetion, such as variable venturi and sonic carburetors, fuel injection, both with mechanical and electronic control systems, advanced catalyst development, both pellet type and monolithic design, feedback induction control systems, high energy ignition systems, computer control of spark advance and exhaust gas circulation.

Each of these programs will continue to be scrutinized carefully to measure contributions to improved fuel economy and reduced emissions at the most cost-effective level.

In addition, programs are in progress that involve major departures from today's engine designs.

The first of these involves a CVCC prechamber engine design program that we are pursuing in conjunction with Honda Motors. The strong point of such an engine is that it will achieve significant fuel economy improvement. The introduction of such an engine is practical, incidentally, only if a NO_x standard of no less than 2 gpm is assured for a sufficient number of years to allow recovery of investment costs to mass produce such an engine. As the president of our company reported to the Senate Subcommittee on Air and Water Pollution over a year ago, assuming successful development, such a design could be incorporated on one engine line—500,000 vehicles—about 3 model years after firm establishment of a reasonable long range NO_x standard. I can report today that to date our development program has been successful, although there are still some technical and economic problems to be resolved. Unfortunately, no congressional action has yet been taken to set the long term NO_x standard at the required level.

In addition to the CVCC, we are working on a programed combustion engine which we term PROCO. Design work on this engine has been progressing at Ford for a number of years. Presently, this program is in competition with our prechamber Honda CVCC program. While there are more design problems to be solved with the PROCO engine, and more time may be necessary to reach the production state, this engine may have better long range potential for improved fuel economy and lower NO_x levels that can be achieved with the CVCC prechamber engine.

In the area of longer range possibilities, Ford has concerned itself with several alternate designs.

Our diesel engine studies suggest that diesels can be adjusted to meet the 1975 standards of the Clean Air Act. We are very concerned, however, with the problems of particulate emissions, smoke, noise, weight, performance loss, cold start problems, and odor emissions associated with diesel engines. Accordingly, our level of development has been restricted. For some time, Ford has had an extensive gas turbine development program. Turbines have the potential to meet the statutory hydrocarbon and CO standards but have questionable NO_x emission

reduction potential. In mid-1972, we found that vaporizing and premixing fuel showed a potential for reducing NO_x to acceptable levels. We also have worked with an Engelhard catalytic combustor and a Zwick reverse-flow combustor which premixes fuel and air. Both devices have a similar potential for reducing NO_x.

It has been known for some time that the operating temperatures of turbines must be raised substantially in order to obtain acceptable fuel economy and to reduce engine size. Ford has taken a different approach to this problem than most companies. This new approach includes replacing the costly high temperature metal alloys with ceramic components that can withstand the high temperature requirements that must be achieved in these turbines. A portion of our work is supported by the Advanced Research Projects Agency of the Department of Defense. We understand the Department of Defense believes that this ceramic technology could have broad applications in many fields.

Ford has worked on the Rankine cycle engine with Thermo-Electron Corp. Much of our recent effort has been directed toward testing a mockup of a Rankine cycle engine in a Ford car to determine cooling air requirements. We found the engine to be extremely complex with poor theoretical thermal efficiency. This would necessarily result in poor fuel economy. There are unresolved major problems which are also severe. These relate to cooling, packaging, difficulty in obtaining projected cycle efficiencies, and engine weight. Since these problems seemed to be of such magnitude as to make this powerplant unattractive, Ford has discontinued its program on the Rankine cycle engine.

We also have developmental programs with two firms on the Stirling cycle engine which is an external combustion hot-air engine. We have worked with Philips of Holland since 1971 and with United Stirling of Sweden, a licensee of Philips, since 1972. The Stirling has potential advantages in fuel economy, emissions, and noise levels that should make it an attractive future powerplant. Our major Stirling engine program is with Philips of Holland. We are jointly engineering a 170-hp Stirling engine for installation in a Torino. This program is proceeding on schedule and we will complete the installation of this engine in the vehicle by the end of the year. To supplement this program, we are installing a small Stirling engine, developed by United Stirling of Sweden, in a Pinto as a test bed to evaluate the Stirling engine's cooling and control characteristics so we can properly size components for the 170-hp engine. Even if development work is successful, the time frame for mass production of this engine would be the mid to late 1980's. Once product feasibility is established for these or any other new alternate power source, a substantial manufacturing task would remain. New processes never before utilized in our industry would necessarily be involved.

Ford also has done extensive developmental work on the rotary engine. We have tried many exhaust treatment systems including catalyst only, reactor only, and reactor plus catalyst, using this latter system together with exhaust gas recirculation. Most of our experience with rotary engines has failed to overcome the poor theoretical thermal efficiency problem which has resulted in a fuel economy penalty. As we have sought means to improve economy, we found the rotary engine to exhibit higher HC and CO levels than other internal combustion engines. Ford has, therefore, discontinued work on the rotary engine

in order to concentrate its technical manpower or more promising alternatives.

Ford has done some pioneering work on electric powerplants for vehicles. We are continuing our development of the sodium-sulphur battery and are utilizing a computer model to evaluate various potential electric car configurations. Even if all our research from here on were successful, we could not be ready for production until the late 1980's.

With the information available to us today, it is our belief that we at Ford have balanced our production design effort with our advance and research effort in a sincere and sensible attempt to make available to our customers the best vehicles we can produce, and still meet Government standards for safety and emission control. We believe that considerable improvement in our programs could be attained in driveability and fuel economy if Federal emission standards could be stabilized for a period of time.

It is essential that Congress establish long-term emission standards as soon as possible. We recognize that the NAS is conducting an in-depth study in this area, the results of which should be available during the third quarter of this year. This should provide factual data to assist Congress in a decision on this question.

In conclusion, let me speak directly to H.R. 10392 which is the subject of this hearing. As indicated at the outset of this statement, there needs to be some coordination and prioritization of research and development programs of ground propulsion systems, both within the Government and in the private sector. Our current grant to the Jet Propulsion Laboratory may help in establishing such priorities. Certainly, we at Ford will give careful consideration to any recommendations which the JPL study develops. In the interim, we have serious questions concerning this legislation on the basis that at least on the surface it appears to duplicate other Government efforts. For example: The Environmental Protection Agency, under its alternative automotive power system program, will spend about $17 million next year in this area (NASA is already supporting EPA in this program.).

The Department of Transportation, through the Urban Mass Transit Administraion, is funding research on alternate propulsion systems for public transportation, including Rankine cycle, electric, and flywheel propulsion system for buses.

The Department of Transportation, through the Federal Railroad Administration, has a $42 million program on high-speed ground transportation research, much of which is directed at alternate propulsion systems.

At the outset, we mentioned other Government efforts by NASA, the Department of Defense, the Postal Service, AEC, and the National Science Foundation. We believe that the outstanding capabilities of NASA could be better brought to bear on the propulsion system problem by supporting EPA and the Department of Transportation who have been charged with this mission and are already underway with what we consider to be excellent and appropriate programs. We believe that it would be more productive to increase support for these groups who, in turn, could contract with NASA as appropriate.

Thank you again for the opportunity to make this report to you today.

Mr. SYMINGTON. Thank you, Mr. Jensen, very much for a fine statement.

Are you familiar with the testimony we received from representatives of the Department of Transportation concerning their investment in long-range research for automotive engines?

Mr. JENSEN. I have read the transcript. It was about a month ago, so I may not have it completely in mind, Mr. Chairman.

Mr. SYMINGTON. Perhaps I could refresh your memory by pointing out that they said that this type of research was something for Detroit to do. That is the way they put it. I asked, "Isn't that rather discouraging, if in fact the industry is not doing what you think they should be doing?" What should we make of all that?

Mr. JENSEN. Mr. Chairman, we feel very strongly that the Government has a role in this field. We do not know exactly what the role should be in relation to the private sector. That is why we made the grant to JPL to hopefully let us know, and give us some direction as to where we should go. We are in the same position you are in that respect.

Mr. SYMINGTON. I think the industry is quite anxious to develop the right working relationship with Government for long-range research of this kind and we want to help them.

Mr. JENSEN. Yes, sir.

Mr. SYMINGTON. The assignments that you list on page 10, except for item 2, DOT's conducting of in-house and funded work on alternative automotive systems, doesn't really touch the system. If mass transit doesn't touch it and EPA's work doesn't do it—they are solving the current problems—you have to hang your hat on the DOT's resolve to do such research work, and they have told us they have resolved not to do it. That is one of the reasons why we think that NASA, which has shown some interest in this type of research, and certainly has a large capability, might be the one to do the work.

Of course, if DOT wants to help fund the work, we would not object to that. We are really not all that far apart. The work should be done. I think you agree that some sort of effort at this time ought to be made to assist the industry in looking down the road.

Mr. JENSEN. We feel that NASA does have great capability. We, too, have worked with them a great deal in our Philco-Ford operation. What we are looking for is hopefully not a competitive group in Government. That is why we are concerned about this particular legislation. We had hoped we would have some kind of coordinated approach so we could attain the same kind of objectives I think we share with you.

Mr. SYMINGTON. Of course, we want to avoid undesirable duplication. We want good minds to think independently and to come up with good ideas, but all with some overview by someone who will sort it out.

With Mr. Brown's indulgence, I will call on Mr. Milford for questions.

Mr. MILFORD. I share your concern about duplication, but I am wondering if we might be off a little bit on communications. Are you primarily referring here to hardware development as opposed to fundamental research in physical principles which could be applied to hardware development?

Mr. JENSEN. I am speaking primarily of hardware development. We do have an interest in basic research at Ford. Our scientists for example are looking down the road—they have to—to the day when petroleum products will not be available. They are looking at things like solar energy and fusion, and the theory that in the future we will have to look toward a different kind of fuel. So, we have that kind of concern, but the discussion today, I think, relates primarily to hardware development.

Mr. MILFORD. I thought the role of NASA was fairly nicely summed up in Mr. Terry's statement on page 9, getting into such things as the study of burning gases and the control of burning gases in this chamber which would be applicable to the industry itself, and incorporating our research on airfoils and turbine blades, which could be applied by the industry as a whole in the building of a better engine. This is the kind of thought I had in my mind.

Mr. JENSEN. I think you and I are talking on the same wavelength. We are concerned about the competitive aspects. For example, there is a turbine contract on which EPA reported to this committee, and more turbinework is contemplated down the road. In this case, there could be some duplication and waste. We should have everyone moving toward the same objective. This should not hamper scientific research. You cannot put too many restrictions on researchers and say, "You have to go in this direction," or you would lose the imagination and initiative which characterizes our great scientific achievements.

Mr. MILFORD. What I am trying to get from you is the identity of certain areas which would improve the powerplant itself such as two areas which have been outlined here in the previous witness' statement, where NASA could fulfill the role not in the making of a better turbine engine but could research out a sector or area that you as a manufacturer can incorporate in making a better engine. I am not sure I am making myself clear.

Mr. JENSEN. I understand what you are saying.

Mr. MILFORD. Those are the kinds of suggestions I would like to hear about.

Mr. JENSEN. My feeling still is that if the $30 million were available, and there were some kind of overriding coordinating force so NASA could do this work in which they have this tremendous capability, it would satisfy any problems we had in this respect.

Mr. MILFORD. Thank you, Mr. Chairman.

Mr. SYMINGTON. Thank you.

Mr. Brown?

Mr. BROWN. Let me just pursue this for a moment, Mr. Jensen.

I couldn't agree with you more that work in this general field needs to be better coordinated, and part of the problem in Congress right now is determining the system by which we will achieve this coordination. That is likewise true in the executive branch. They have a few problems of their own in terms of how to get coordination. For example, the lead responsibility for emission control problems is obviously with the Environmental Protection Agency. Their concern, however, with fuel efficiency is peripheral, except to the degree that it may happen to coincide, in some respects, with emission control policy.

The question of fuel efficiency is now probably more within the purview of the proposed Energy Research and Development Adminis-

tration, which Congress may likely approve and establish, and which would be responsible for both. The supply, and to some degree the demand for energy in this country, as far as research and development is concerned.

Now which should be a lead agency in a project to establish both a more emission-free and at the same time energy-conserving automobile? Should it be ERDA? Should it be EPA, or should it be DOT which has a mandate in general on transportation? This is where the problem lies.

Now, we have in NASA a general purpose research and development organization which can—and I think this is a widely shared view—which can contribute to the solution of this problem. But obviously the criticism is quite correct. It does not have a specific mandate that deals with either emission controls or cleaner engines. It is not trying to usurp ERDA as far as energy research and development is concerned. Certainly it does not want to take over DOT. But nevertheless, it has a long-demonstrated capability of handling the kind of problems which need to be solved in order to attack this.

Now, I think our purpose in drafting this legislation is to try, with the help of witnesses, such as yourself, to create a framework within which this capability can be utilized. Frankly, I do not consider the legislation to the perfect. I think it would be more desirable, instead of the rather blunt mandate which the bill gives to develop ground propulsion systems which are energy conserving and have clean emission characteristics, that we ought to indicate that their authorization shall extend to research and development aimed at solving problems in these areas, in coordination with or under the direction of the appropriate agency dealing specifically with the problem.

But I think those kinds of changes in the legislation can be readily made if we agree that there is a problem and that NASA has the capability to solve it and it ought to be engaged.

Would you react to that little speech?

Mr. Jensen. I think, you and I are talking on the same wavelength and have the same concerns and obviously the same objectives. If we did not have the same problems and questions we would not have provided a grant to JPL. We will need some help and guidance. We want to know that we are going on the right path.

Mr. Brown. I want to compliment you and your company for having given that grant to JPL. I think JPL is eminently qualified to give you an extremely valuable report. They are themselves doing some work on emission controls and more efficient engines. They have had long experience in working with private contracts and the private enterprise sector. I think they are resposive to the needs of all parties involved. And while I would prefer that we pass this bill tomorrow and give them a specific authorization to continue and expand what they are doing—essentially, that is what we are seeking—I would feel that if we cannot get the bill through immediately that we would be well served to be guided by the JPL report. After all, they are a part of NASA. So you have called on NASA, in effect, for assistance or consultative services in this regard. I will defer further quesions, Mr. Chairman.

Mr. Symington. Mr. Jensen, we do need to get on to our next witness, but you say on page 9 of your statement that you have a balanced

effort and you balenced it with your research effort. How do you mean you balanced it? Do you mean dollar for dollar or do you mean you found what you deem to be an appropriate emphasis on each?

Mr. JENSEN. Yes. For example, the material which was in the transcript, and I speak of the tables which were mentioned earlier show that Ford was spending a greater percentage than our competitors of our total R. & D. budget on control of emission. The transcript said it was 26.3 percent but the latest number is 26.79. This is one phase of this balancing process. The other phase relates to how much we are spending on alternate power sources as compared to total emission control. On the engineering portion of research and development, we spent $221 milliion on total emission-related projects in 1973. Of that total the final number for 1973 spent on alternate power source development was $26,452,000.

In respect to personnel we had the equivalent of 5,600 people working in total emission research. Of that total about 567 were working on alternate power sources. I do not know whether that is too many or too few. That ist why we are talking with JPL. But we have tried to balance it.

Mr. SYMINGTON. The areospace industry tends to invest a fixed percentage of its sales dollars in R. & D. and the Government tends to engage in fund matching to help them do that. How do you feel that the industry, or at least Ford feels about that? How do you determine the level at which you will invest in R. & D. on, let us say, alternative propulsion systems?

Mr. JENSEN. I am not familiar with the aerospace industry proportion for R. & D. Of course, we react to Government laws and requirements. The amount which we spent on alternate power sources, R. & D. for example in 1970—the year before the clean air amendments were adopted, on December 31, 1970—was around $8 million. Now, as I indicated in 1973, alternate power source R. & D. expenditures are up to $26.5 million. A good portion of that is designed to meet long-range Government requirements in the public interest. You people in Congress speak for the public. You are the ones who have to indicate what the long-range goals should be and we have to react. So it is in part a reaction rather than being based completely on our initiative.

Mr. SYMINGTON. In other words, the curve of your R. & D. investment apparently goes up with Government interest and presumably would tend to decline without it.

Mr. JENSEN. Correct. Naturally, we have an overriding interest obviously in being competitive. We want to come out with the best alternate power system before Chrysler and General Motors. We want to have the best fuel economy and lowest cost and so forth. That is our overriding interest but we react to Government interest too.

Mr. SYMINGTON. Thank you.

Mr. BROWN. Mr. Chairman, may I ask just one clarifying question.

Mr. Jensen, this is somewhat peripheral, but not entirely. I am interested that you indicated you are doing some research on batteries.

Mr. JENSEN. Yes, sir.

Mr. BROWN. Could you provide the committee with some additional information on your work in developing these batteries. And I ask you also if the company has given any thought to the possibility that there might be at least a small but growing market for a battery-

powered vehicle in certain areas of cities which might be limited to access by a low-powered, limited velocity, vehicles only, and from which internal combustion engines might be prohibited. And believe it or not there will be increasing numbers of such communities.

Mr. JENSEN. We will be glad to supply that information, Mr. Brown.

Mr. FRANK R. HAMMILL, Jr.,
Committee on Science and Astronautics, House of Representatives, Suite 2321, Rayburn House Office Building, Washington, D.C.

DEAR MR. HAMMILL: I am responding to the questions posed in your letter of June 17, 1974.

1. Does the information on pages 103 to 109 of the February 4, 5, and 6 hearings of the Subcommittee match the information in your own files?

There are some inconsistencies in the data as reflected on pages 103 to 109 in the February 4, 5 and 6 Subcommittee hearing record. In this regard, we have noted the appropriate corrections on a copy of the respective record material which is attached hereto.

2. Do you have an estimate of the future expenditures of your company in the same categories that are listed in our February hearing record?

We cannot realistically forecast expenditures on such a definitive category basis. Generally, wherever we find it necessary to portray such projected data we do so in terms of current year expenditures adjusted to reflect anticipated inflationary trends.

3. What mileage goals does your company have for each category of vehicle that you market, using the EPA mileage test cycle?

Mileage goals for each carline/engine family configuration are established as a function of our city-suburban driving cycle and other performance criteria. We believe that the EPA mileage test cycle, especially as used during the 1974 model year, is totally urban oriented and therefore not fully representative of overall normal driving patterns. The EPA has amended this test cycle in 1975 to include a "highway" test sequence and we are presently evaluating this revised methodology.

As you may know, we have initiated a number of broadly based product improvement actions designed to reduce fuel consumption through car and truck component innovations, weight reductions and new small vehicle programs. The new Mustang II in 1974, the soon to be introduced mid-size Granada and Monarch vehicle lines as well as product features such as the widespread use of radial ply tires serve to demonstrate Ford's overall commitment to fuel economy measures. In addition, fuel economy related changes to engine, axle, transmission and carburetor componentry are planned or under investigation for 1975 and future model years.

4. Does your company have any vehicle weight goals? If so, what type of weight mix do you anticipate?

One rather basic goal of future product programs is to maximize interior room and comfort levels as well as handling and ride characteristics within certain design objectives such as smaller overall exterior dimensions, lighter total vehicle weight, and of course, better overall fuel economy performance. Consequently, rather specific weight goals are established as part of the initial approval process for each new vehicle program. These weight objectives are closely monitored throughout the product development process from the very early planning stages through the finalization of the product packages. In addition, weight reduction programs are constantly pursued for short-term application with respect to various design improvements and the increased substitution of light weight material for the more conventional ones. We anticipate, therefore, that excluding the weight effects that may occur as a result of government mandated programs, the average weight of our new vehicles will decline in future years both as a result of new weight reduction product innovations and a more pronounced small car market orientation.

5. What restraints does your company face on phasing in the stratified charge engine?

A major restraint precluding the timely phase-in of the stratified charge engine is the uncertainty of future NO_x emission standards. As I indicated in my testimony "The introduction of such an engine (CVCC pre-chamber) is practical, incidentally, only if a NO_x standard of no less than 2 gpm is assured

for a sufficient number of years to allow recovery of investment costs to mass produce such an engine. As the President of our Company reported to the Senate Subcommittee on Air and Water Pollution over a year ago, assuming successful development, such a design could be incorporated on one engine line (500,000 vehicles) about three model years after firm establishment of a reasonable long range NO_x standard. I can report today that to date our development program has been successful, although there are still some technical and economic problems to be resolved. Unfortunately, no congressional action has yet been taken to set the long term NO_x standard at the required level."

6. What time frame for production does your company see for the various alternative technologies that your statement referenced?

Assuming the establishment of a long range 2.0 NO_x standard as noted above, a stratified charge engine could be produced on a limited basis by the 1978–79 model years. The "in production" time frame for other alternative propulsion systems is as follows:

Turbines—Mid to late 1980's.
Stirling—Mid to late 1980's.
Rankine—No plans.
Rotary—No plans.
Electric—Late 1980's if at all.
Diesel—Early 1980's.

7. Could you explain why the domestic automobile manufacturers in the United States all market basically the same engine types, while foreign manufacturers manufacture varying engine types? In other words, why is there not a mix of propulsion systems and engines from the U.S. manufacturers?

The contention that foreign manufacturers offer a greater variety of propulsion systems than their U.S. counterparts is somewhat overstated. As a worldwide proposition, the internal combustion engine remains the primary source of automotive propulsion. For most other engine configurations, such as the Wankel, the CVCC, and the diesel powerplants, it should be noted that the former are of recent origin and power only a very minor portion of the world's total vehicle population. Furthermore, due to circumstances noted in my testimony, such as an overly stringent U.S. NO_x standard, poor fuel economy characteristics, or the myriad of problems associated with diesel operation, these respective powerplants simply are not yet suitable for the U.S. market. Also, it should be noted that where a particular engine development simply doesn't work out in the U.S. market, a foreign based manufacturer can either absorb the product in his "home" market or otherwise limit his overall financial liabilities.

Respectfully submitted,

D. A. Jensen.

Attachment.

The three largest domestic automobile manufacturers, Chrysler, Ford and General Motors, have expended $422.6 million in 1972 and $737.3 million in 1973 (estimated) on emissions control research and development or a total of $1.16 billion in the last two years. The largest portion of this amount was expended for capital items, equipment and facilities, needed for the production and assembly of emissions control devices, especially catalytic converters. In addition, expended test and research facilities for emissions control were included in the capital expenditures. Table 1 summarizes the emissions-related expenditures by the largest domestic manufacturers and compares them with total research and development expenditures. It shows that capital expenditures were 29% and 46% of total emissions expenditures in 1972 and 1973, respectively.

Over $19 million in 1972 and $30 million in 1973 were reported by the manufacturers specifically for catalytic converter research. The actual amount is much higher than that, however, because most of the money expended by Ford on engineering development of the catalyst was included in 1975/76 control system development and the catalyst portion cannot be separated from the total.

Emissions expenditures were utilized for projects relating to: (1) equipment and engine development directed towards meeting the statutory standards for hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x); (2) basic emissions research, (3) testing and certification of production vehicles; (4) research on advanced emission components, including catalytic converters; and (5) research on alternate power sources. Detailed listings of expenditures

by individual projects are attached for each of the three major domestic manufacturers; the exhibits are from the manufacturers' Application for Suspension of the 1976 Automobile Exhaust Emissions Standards.

TABLE 1.—SUMMARY OF EMISSIONS EXPENDITURES

	1967	1968	1969	1970	1971	1972	1973 [1]	Total 1967–73 (percent)
Total emissions expenditures (millions of dollars) (includes capital spending):								
General Motors	51.2	39.7	65.0	119.9	181.6	237.9	350.7	1,047(53)
Ford	50.7	35.6	52.7	67.0	131.9	164.9	340.1	843(42)
Chrysler	2.9	4.4	6.6	9.0	14.4	19.8	46.5	104(5)
Total	104.8	79.7	124.3	195.9	327.9	422.6	737.3	1,994
Capital expenditures (millions of dollars):								
General Motors	27.2	6.5	13.9	39.8	44.9	90.0	203.7	437.0
Ford	27.3	9.3	16.4	15.5	41.6	33.0	131.1	274.2
Chrysler	([2])	([2])	([2])	0.3	1.0	1.2	3.4	[3] 17.7
Total emissions as a percent of total R. & D.[4]:								
General Motors	3.6	4.5	5.9	9.8	14.0	15.6	15.0	
Ford	7.2	7.2	8.5	11.5	17.5	21.1	26.3	
Chrysler	4.0	4.7	6.3	10.6	14.9	15.0	20.9	
Total R. & D. (millions of dollars):								
General Motors	664	763	852	808	900	945	970	
Ford	325	359	423	453	513	621	796	
Chrysler	76	84	95	82	90	124	150	

[1] 1973 expenditures are estimated.
[2] Not available.
[3] 1970–73.
[4] Does not include capital expenditures.

TABLE 2.—ALTERNATIVE POWER SOURCE RESEARCH DIRECT EXPENDITURES

[In millions of dollars]

	1967	1968	1969	1970	1971	1972	1973	Total 1967–73
General Motors	1.64	4.74	8.46	11.33	18.92	20.80	23.69	89.58
Ford	4.81	4.87	6.56	7.97	12.99	20.33	28.55	81.92
Chrysler	NA	NA	NA	.10	.30	.80	3.5	4.70
Total								

TYPES OF ALTERNATIVE POWER SYSTEMS

1. *G.M.*—Rankine cycle (steam), stratified charge, electric, gas turbine, Stirling, rotary, and Honda CVCC evaluation. "GM's expenditures for emissions control applicable to the rotary engine *do not* include the approximately $50 million forecast to be paid over the period 1970–1975 for the rights to produce this engine."

2. *Ford.*—Stratified charge (PROCO and fast burn), diesel, Rankine cycle, Stirling, rotary, turbine, pre-chamber spark-ignited, and auxiliary power units (APU).

3. *Chrysler.*—Gas, Turbine, Rankine cycle, TCCS evaluation, Brayton cycle, rotary, and Honda CVCC evaluation.

ATTACHMENT 1

EMMISSIONS CONTROL: DOLLAR RESOURCES AND PROFESSIONAL TECHNICAL MAN-YEARS, CALENDAR YEARS, 1970–74

[Dollars in millions]

	1970 actual		1971 actual		1972 actual		1973 estimate		1974 estimate	
	Dollar resources	Professional technical man-years	Dollar resources	Professional technical man-years	Dollar resources	Professional technical man-years	Dollar resources	Professional technical man-years	Dollar resources	Professional technical man-years
Engine modification	$3.7	166	$4.2	170	$5.3	233	$8.5	320	$9.8	370
Elect. Eng. control	.4	12	1.0	38	1.1	48	1.5	60	3.2	120
Thermal reactors	1.9	79	3.0	101	1.9	84	2.0	75	2.3	85
Catalytic reactors	1.4	70	3.5	114	7.0	305	12.6	475	13.0	490
Alternative prop. systems	.1	2	.3	11	.8	35	3.9	145	6.0	225
Total	7.5	329	12.0	434	16.1	705	28.5	1,075	34.3	1,290
Administrative support	1.2		1.4		2.5		2.8		3.0	
Total	8.7		13.4		18.6		31.3		37.3	
Capital expenditures	.3		1.0		1.2		15.2		12.5	
Total resources	9.0		14.4		19.8		46.5		49.8	

Note: These figures have been prepared by using analysis techniques and are taken from official books of record.

Source: Chrysler Corp. "Application for Suspension of the 1976 Motor Vehicle Emissions Standards," May 1973, p. III–B–3.

ATTACHMENT 2

FORD MOTOR CO., 1967–76 EMISSION CONTROL EXPENDITURES AND EQUIVALENT HEADCOUNT

Project No. and description	Calendar year expenditures (millions): 1967	1968	1969	1970	1971	[1] 1972	1973	[2] 1974	[2] 1975	[2] 1976	Calendar year average equivalent headcount: 1967	1968	1969	1970	1971	1972	1973	[2] 1974–76
Research and engineering variable effort:																		
1. R. & D. of systems designed for meeting 1975 Federal Standards				$0.3	$2.0	$9.4	$34.4							16	79	288	1,181	
2. R. & D. of systems designed for meeting 1976 Federal standards		$0.1	$0.3	.4	1.2	3.3	9.1					3	15	18	47	112	284	
3. R. & D. of systems designed for meeting 1974 California standards		(3)	(3)	.6	3.4	16.4	24.3					1		26	143	557	996	
4. Catalyst component research standards	$0.4	.5	.6	.9	1.9	2.9	4.6				18	27	29	49	79	118	134	

5. Reactor manifold component research	.2	.4	.3	.6	1.3	.8	0.2				11	15	15	28	52	27	7	
6. EGR system research	.1	.2	.2	.3	.9	1.0	1.1				5	12	9	14	34	36	44	
7. Ignition system component research	.1	.2	.2	.7	.9	.5	.4				8	11	19	35	27	17	12	
8. Other basic engine research	1.0	.6	.8	.4	.3	.3	.7				55	32	40	17	12	7	23	
9. Induction and fuel systems component research	.9	.9	.9	1.5	1.9	2.2	2.5				50	43	48	77	67	64	82	
10. Fuels and lubricants research	.2	.4	.3	.4	.4	.5	.5				7	17	12	16	13	12	11	
11. Research in physics and chemistry related to HC, CO, NO[3]	.1	.1	.1	.3	.2	.1	.3				6	4	7	13	8	4	8	
12. Alternate power source research	4.8	4.9	6.6	8.0	13.0	20.3	26.5				194	219	240	253	318	446	618	
13. Research on potential internal combustion engine emissions	(3)		(3)	(3)	.1	.1	1.0							1	1	2	34	
14. Testing and data analysis research	.2	.3	.8	1.1	2.4	3.8	3.5				7	26	57	61	16	1441	55	
15. Evaporative emission research	.4	1.0	.7	.4	.7	1.2	2.4				22	59	34	21	29	51	126	
16. Crankcase emission research	(3)	(3)		(3)	.1	(3)									1	1		
17. Closed-loop emissions research	(3)	(3)	(3)	.1	.3	.8	2.4					1	1	3	9	16	81	
18. Emission development certification, and production emission engineering	1.1	1.5	1.7	2.2	8.5	12.4	23.0				68	103	104	123	409	542	973	
19. R. & D. in support of production exhaust emission control	5.6	5.9	9.4	12.7	19.2	18.0	14.0				298	296	493	684	874	685	562	
20. Air quality research	.1	.3	.4	.6	.7	.8	.8				2	4	4	9	8	9	9	
21. Coordination and communication	.1	.4	.7	1.3	1.0	.9	1.4				4	10	32	37	29	28	41	
Total variable effort	15.3	17.7	24.0	32.8	60.4	95.7	153.1	162.3	172.0	182.3	755	883	1,159	1,501	2,345	3,160	5,381	5,381
Support effort	8.1	8.6	12.3	18.7	29.9	36.2	55.9	59.3	62.9	66.7	315	318	389	517	752	881	1,139	1,139
Total research and engineering	23.4	26.3	36.3	51.5	90.3	131.9	209.0	221.6	234.9	249.0	1,070	1,201	1,548	2,018	3,097	4,041	6,520	6,520
Other emission control expenditures:																		
Tooling	7.6	6.3	9.9	4.8	10.9	14.7	69.2	106.3	115.7									
Facilities	16.2	2.8	4.2	9.2	27.2	15.2	50.9	68.5	70.1									
Launching	3.5	.2	2.3	1.5	3.5	3.1	12.0	25.2	14.0									
Total other emission expenditures	27.3	9.3	16.4	15.5	41.6	33.0	131.1	200.0	199.8									
Total expenditures	50.7	35.6	52.7	67.0	131.9	164.9	340.1	421.6	434.7									

[1] Excludes 1973 model recertification.
[2] 1974–76 research and engineering cost and manpower levels are projected equal to the 1973 projection adjusted for anticipated inflation.
[3] Less than $50,000.

Note: Headcount includes salaried, agency, hourly and overtime equivalent personnel.

Source: Ford Motor Co., "Request for Suspension of 1976 Motor Vehicle Exhaust Emission Standards," June 18, 1973, sec. 3 schedule B.

ATTACHMENT 3

SCHEDULE B

GENERAL MOTORS CORP. EMISSION CONTROL EXPENDITURES, CALENDAR YEAR BASIS 1967–76

[In thousands of dollars]

Control system projects	1967	1968	1969	1970	1971	1972	Projected 1973	1974	1975	1976
1. Catalytic converters—converter	$50	$205	$243	$1,592	$4,089	$4,775	$7,477	$7,680	$8,161	$4,566
2. Catalytic converters—other						4,306	5,166	7,192	7,628	
3. Questor system						414	1,132	2,593	2,566	2,576
4. Single catalyst system (combined reduction HC,CO, and NOx)						11		64	99	49
5. Crankcase blowby controls (PCV)	1,342	1,530	494	218	492	380	361	377	345	355
6. Air injector reactor system (AIR)	1,327	1,005	1,016	2,429	3,426	3,913	3,064	3,183	2,931	2,826
7. Exhaust gas recirculation (BOR)	13	36	230	1,073	3,013	5,495	4,959	4,405	3,802	3,552
8. Spark control systems (TCS, SCS)	338	611	1,018	3,738	3,469	4,298	3,624	3,054	3,581	3,623
9. Manifold heat (EEE)	16	32	45		1,570	979	1,284	1,353	1,602	1,917
10. High-energy ignition	463	112	217	1,117	2,695	3,270	3,116	4,161	3,802	3,765
11. Electric fuel pump						149	171	313	219	231
12. Exhaust system (long life)						153	146	155	151	144
13. Fuel filler neck change						131	128	150	105	106
14. Controlled combustion system (CCS)	1,192	1,210	1,383	2,792	2,811	1,621	1,554	1,056	1,257	1,605
15. Manifold reactors		111	254	579	516	889	612	670	752	986
16. Evaporative emission system	563	958	1,057	3,193	2,796	2,179	1,981	1,969	1,331	1,919
17. Fuel injection	52	459	1,549	3,055	4,128	1,270	336	395	570	520
18. Asbestos, rubber, etc						74	47	61	55	66

19. Gaseous fuels—LPG, LNG, CNG	8		107	176	139	91	110	107	106	108
20. Fuel specifications	22	95	176	893	2,363	841	747	755	848	920
21. Smoke, odor	247	315	466	827	980	1,395	1,556	1,510	1,741	1,823
22. Carburetion—current methods	2,932	2,532	3,030	5,208	7,785	7,846	7,319	8,081	9,475	10,219
23. Carburetion—future models	1,797	2,334	2,000	2,068	4,186	11,494	10,518	8,044	7,739	7,682
24. Emission testing and analysis—end of line	533	1,550	2,019	3,318	7,322	9,495	8,908	9,086	9,302	9,952
25. Emission testing and analysis—other	1,343	1,290	2,177	3,180	7,064	8,049	8,269	8,813	9,602	9,955
26. Alternate power sources	1,641	4,743	8,455	11,333	18,923	20,801	23,685	22,383	22,479	22,202
27. Other	1,016	1,371	4,370	2,315	3,814	4,296	4,090	3,912	4,362	4,724
Subtotal direct expenditures	14,898	20,499	30,306	49,104	81,581	98,616	100,360	102,972	105,115	103,843
Facilities	17,872	5,108	6,172	23,451	30,471	41,828	112,814	176,956	67,787	33,751
Tools	9,323	1,389	7,749	16,289	25,412	48,165	90,890	167,066	56,481	9,849
Total direct expenditures including facilities and tools	42,093	26,996	44,227	88,844	137,464	188,609	304,064	446,994	229,383	147,443
Allocated costs	9,053	12,006	19,584	30,132	44,133	48,515	45,936	48,006	50,617	49,557
Total, excluding General Motors' support of Motor Vehicles Manufacturers Association	51,416	39,002	63,811	118,976	181,597	237,124	350,000	495,000	280,000	197,000
General Motors' support of Motor Vehicles Manufacturers Association[1]	*101*	*708*	*1,230*	*957*	50	740	740	740	740	740
Total expenditures	51,247	39,710	65,041	119,933	181,647	237,864	350,740	495,740	280,740	197,740

[1] Forecast of Motor Vehicles Manufacturers Association support is assumed to be approximately the same as 1972.

Note: The above data display a summary of expenditures for the years 1967 through 1972 and a projection through 1976.

Source: "General Motors Request for Suspension of 1976 Federal Emissions Standards," June 20, 1973, app. 29, schedule B.

Hon. GEORGE E. BROWN, Jr.,
Committee on Science and Astronautics, House of Representatives, Suite 2311, Rayburn House Office Building, Washington, D.C.

DEAR MR. BROWN: In reading the transcript of the hearing before the Subcommittee on Space, Science and Applications of the Committee on Science and Astronautics on June 12, 1974, I was impressed with one of your statements. You said on page 347:

"Now, I think our purpose in drafting this legislation is to try, with the help of witnesses such as yourself, to create a framework within which this can be utilized. Frankly, I do not consider the legislation to be perfect. I think it would be more desirable instead of the rather blunt mandate which the bill gives to develop ground propulsion systems which are energy conserving and have clean emission characteristics that we ought to soften that a little bit and indicate that their authorization shall extend to research and development aimed at solving problems in these areas in coordination with or under the direction of the appropriate agency dealing specifically with the emission.

"But I think those kinds of changes in the legislation can be readily made if we agree that there is a problem and that NASA has the capability to solve it and it ought to be engaged."

This is an excellent expression of the feeling we, at Ford Motor Company, have in respect to H.R. 10392. We would endorse your statement and support your proposal. Your suggestion provides a means of utilizing the capability of NASA in coordination with other appropriate government agencies which have been assigned specific tasks by Congress.

If you wish, this letter can be utilized in the record of the hearing.

Thank you for your courtesy and consideration.

Sincerely,

D. A. JENSEN.

Mr. GEORGE E. BROWN, JR.,
Committee on Science and Astronautics,
House of Representatives,
Washington, D.C.

DEAR MR. BROWN: At the hearing of the Subcommittee on Space, Science and Applications of the Committee on Science and Astronautics you asked for further information regarding Ford Motor Company's research on electric powered vehicles.

In our judgment in order to develop electric vehicles with reasonable broad usefulness, it is necessary to have batteries with improved energy storage. Therefore, the Ford program has been aimed mainly at the development of a sodium-sulfur battery which in our judgment has the best potential as an energy source for electric vehicles.

I am enclosing the text of remarks made by Dr. Dale W. Compton, Vice President, Scientific Research Staff, Ford Motor Company at the RANN Symposium, National Science Foundation, Washington, D.C., November 19, 1973. This, I think, is responsive to your inquiry. This can be put in your hearing record if you desire.

Under separate cover I am forwarding to Frank Hammill, Jr., Committee Counsel, several rather lengthy reports on our research and development efforts on electric vehicles. These may be useful as reference documents.

If I can be of further assistance, please feel free to call on me.

Sincerely,

D. A. JENSEN.

News Release

Research and Engineering Center, Dearborn, Mich. 48121
Telephone: (313) 322-8800

IMMEDIATE RELEASE

Following is the text of remarks by Dr. W. Dale Compton, vice president - Scientific Research, Ford Motor Company, at the RANN Symposium, National Science Foundation, Washington, D. C., November 19, 1973:

The energy crisis is probably the most discussed topic in the news these days -- and for good reason. It touches everyone. We've been told that the United States should expect severe heating oil shortages this winter and gasoline shortages appear likely this winter and certain by next summer. With every new day, consumer coupon rationing of gasoline and heating oil is being discussed more actively.

Even as recently as a year ago, most of us wouldn't have predicted that before the end of 1974, we might be forced to accommodate to the unpleasant task of readjusting our way of life to this drastic change in energy availability.

And not only will personal comfort be affected in the years ahead, but also our manufacturing productivity will be hit hard. With world energy consumption expected to double by the 1980's, we must look at every alternative for expanding our energy resources.

We in the automobile business often are asked why we haven't built electrically-powered vehicles to alleviate the problem of exhaust emissions and now to combat the shortage of gasoline. First, and as we will discuss further in a moment, the performance of presently feasible electric vehicles just does not measure up to the performance of vehicles powered by internal combustion engines. It simply cannot perform on the highway in a fashion that is typical of the standard gasoline-powered vehicle.

As for emissions, the traditional answer is that electric vehicles would merely transfer the pollution problem from the vehicle to the electrical generating plant. Therefore, converting to electric vehicles would result in no net benefit. This answer is really a bit too simple. Whether it is cheaper and easier to reduce pollutants at a central power generating station or in the exhaust of each vehicle is a complex problem for which there is probably no single best answer.

Such factors as the nature and extent of the fuel supplies, the type and concentration of the pollutants that can be tolerated, the location at which the pollutants are emitted, the local meteorological conditions and the status of the various control technologies must be considered.

Within the present technology of electric and internal combustion-powered vehicles, the overall system efficiency, as measured by the fraction of the energy in the primary fuel that is converted to useful torque at the wheels of a vehicle, is essentially the same.

Clearly, if significant improvements are made in the efficiencies of any of the sub-elements -- either in the generation, transmission or utilization of electricity -- this could affect the attractiveness of electric vehicles. Thus, we must continue to examine the various alternatives for energy production and utilization and the trade-offs that are possible within this complex problem.

For a number of years, Ford scientists and engineers have studied the aspect of this problem that deals with the conversion and storage of electrical energy and the extent to which electricity can compete favorably with liquid fuel for powering vehicles.

This morning I'd like to discuss with you the development of a new storage system and the possible advantages that it can offer to us over the standard lead-acid battery system in both the storage of extra electrical energy and in providing energy for mobile vehicle propulsion. For the next few minutes let's concentrate on the development of a new battery technology.

As a basis for orientation, we'll compare the performance of a 3,200-pound vehicle when propelled by either an internal combustion engine or a direct current electric motor. This weight class is chosen arbitrarily, but it is reasonably representative of the compact class vehicle. The projected operating characteristics are shown in the two columns on the left of Figure 1 for an electric vehicle with lead-acid batteries and on the right for a standard 2.3-liter internal combustion engine with automatic transmission.

City Vehicle-Performance
(3200 Lb. Gross Wgt.)

	Electric Drive (Lead-Acid Battery)		ICE
Payload (Lbs.)	300		800
Motor	30 hp.	17 hp.	2.3L w/Auto Trans.
Range Per Charge (Miles)			
.20 mph	48	58	273
. City Driving	28	34	233
Acceleration			
Distance in 10 Sec. (Ft.)	365	230	373

Figure 1

An electric vehicle with the characteristics described in the far left column has reasonably high performance, as measured by the maximum distance traveled in ten seconds, starting from rest. As this suggests, it is technically possible to build an electric vehicle that is essentially equivalent to the internal combustion vehicle by this single criterion, but the range and payload of the electric vehicle are very limited. The middle column indicates the limited trade-offs that can be effected between performance and range for the same vehicle — still powered with lead-acid batteries. Not only are the range and payload of this vehicle limited, but it would have unacceptable performance. The column on the right gives the data for this vehicle weight when powered by an internal combustion engine. Obviously, neither of the electric vehicles has the desirable operating characteristics of the internal combustion engine.

Figure 2 presents the projected operating costs for these same vehicles. For purposes of this comparison, the gasoline tax has been removed from the figures on the right. The limitation in the performance of the electric vehicle, although somewhat affected by motor design and controller design, is determined almost entirely by the battery system. This poor performance can be traced directly to the problem of how

much battery weight can be accommodated in the electric vehicle. Thus, it relates directly to the low energy density of the lead-acid battery. The total operating cost of the system also is affected strongly by the relatively limited number of charges and discharges that the lead-acid batteries can sustain, for this determines the battery lifetime. This leads us to believe that only through the development of battery systems superior to those of lead acid can a major advancement in electric propulsion be achieved.

City Vehicle-Operating Costs
(3200 Lb. Gross Wgt.)

	Electric Drive (Lead-Acid Battery)		ICE
Motor	30 hp.	17 hp.	2.3L w/Auto Trans.
Fuel Cost (c/Mi.)	1.1*	0.9*	1.4*
Operating Cost (c/Mi.)	4.2	3.8	2.1
Total Vehicle Cost (c/Mi.)	8.3	7.8	5.6

*Taxes not included

Figure 2

What are the potentials in terms of a chemical storage system?

Figure 3 depicts the energy densities of some common systems in units of watt hours per pound. The higher the energy density, the less battery weight that one needs for a given performance.

Energy Densities of Some Common Systems
(Watt-Hrs./Pound)

	Theoretical	Actual
Lead-Acid	49	10
Silver-Zinc	230	50
Sodium-Sulfur	350	100*
Zinc-Oxygen	495	60*
Lithium-Sulfur	660	100*
Lithium-Copper Flouride	646	100
Lithium-Chlorine	990	250
Gasoline	6000	1200

*Projected

Figure 3

Starting with lead acid, we find the energy density in watts per pound increasing as we progress from the lead-acid system to the sodium sulfur system and finally to the lithium chlorine system. For purposes of comparison, the energy density for gasoline, which is substantially greater than that of the battery systems, also is given. Even though the energy density of gasoline cannot be achieved by the chemical storage systems described above, a factor of ten improvement in range would make the electric vehicle much more attractive. An improvement in energy density of the battery system by this factor over lead acid would enhance materially the attractiveness of the electric vehicle. This, in fact, seems possible. There are other considerations, however.

In addition to the energy density, the battery system must have a high power density, a long life (which means many charges and discharges) and low cost.

Let me now mention very briefly the role that energy storage devices can play in improving the efficiency of electrical generating and transmission systems. Improved efficiency for the electrical generating system can be achieved by operating it near peak power at all times with a capability for storing any electrical energy that is not needed immediately. Thus, the overall efficiency for power generation is improved if

energy can be generated, say at night, for use during the peak demand periods that occur during the day. Improvements in energy and power density and lifetime of batteries over that available from lead-acid batteries are also needed for power system applications. Thus, the criteria for the batteries are very similar.

After a thorough study of the various possible battery systems, we concluded that the sodium sulfur system offers the best chance of achieving all of the objectives we seek and thus of providing improved capability for both electric propulsion and power system peak load leveling.

The development of the sodium sulfur battery began at Ford Motor Company a decade ago -- in 1963. During this ten-year span, we have been concerned with the development of engineering prototypes, as well as with understanding the fundamental mechanisms that take place in this system.

Figure 4 illustrates the nature of the sodium sulfur battery and shows how it differs from the lead-acid battery. On the left is a diagram of the standard lead-acid battery with solid electrodes of lead and lead dioxide, separated by sulfuric acid, the liquid electrolyte. On discharge, the energy is extracted by the external circuit and both the electrodes undergo chemical change. The number of charges and discharges are limited, at least in part, by irreversible changes that take place in the electrodes.

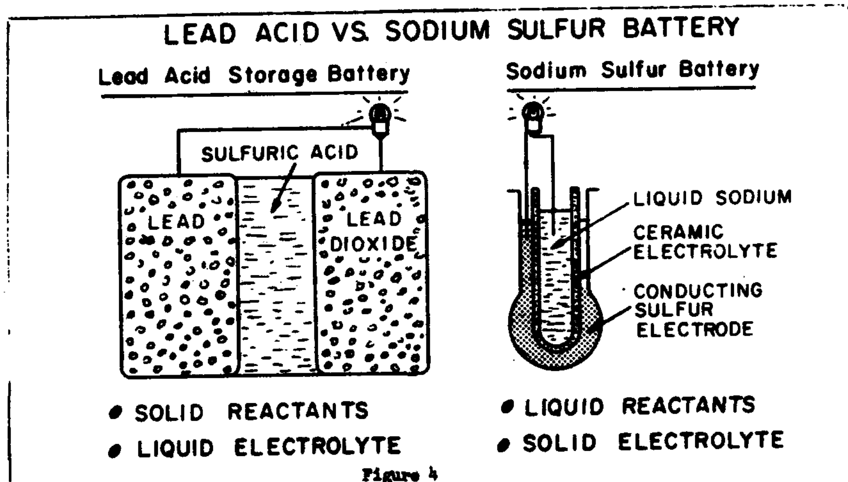

Figure 4

By contrast, the sodium sulfur battery has liquid electrodes, sodium and sulfur, which are separated by a solid electrolyte — a form of ceramic known as beta-alumina. During discharge, a sodium atom gives up an electron to the external circuit, migrates through the solid electrolyte and reacts with the sulfur on the other side to form a compound of sodium and sulfur. Ideally, there is no chemical or physical change that takes place in the ceramic electrolyte during the charge or discharge, and the chemical changes of the electrodes are completely reversible. The characteristics of the inert electrolyte make possible important trade-offs between the energy and power. In the sodium sulfur battery, the total stored energy depends only upon the total weight of the sodium and sulfur, whereas the power density is related directly to the total surface area of the ceramic electrolyte.

For a vehicle, the stored energy is related directly to the achievable range; whereas, the power density is related to the achievable acceleration of the vehicle. Since one of the most expensive components of the battery is the ceramic electrolyte, it will be advantageous economically to tailor this battery to the amount of ceramic that is used. Where weight is critical, as in the vehicle, a high energy and power density is required.

The objectives of the development of the sodium sulfur battery are shown in Figure 5. For electric propulsion, we believe we need:

. An energy density of 100 watt hours per pound

. A power density of 100 watts per pound

. A durability of five years (which can be expressed in terms of a desired charge and discharge of about one thousand cycles) and

. A cost of approximately two to three dollars per pound

Sodium Sulfur Battery
Development Objectives

	Electric Vehicles	Load Leveling
Energy Density (Watt Hrs./Lb.)	100	25
Power Density (Watt/Lb.)	100	25
Durability (Yrs.)	5 (1000-Cycles)	25
Cost ($/Kwhr.)	20	5-15

Figure 5

For power system load leveling, we believe the energy density and power density can be somewhat lower since weight is not such a problem. However, the durability should be about twenty-five years. We project the desired cost for this application to be between five and fifteen dollars per kilowatt hour of stored energy -- somewhat lower than the projected cost of batteries that are to be used for electric propulsion.

As with any new application, several problems must be solved before this system can become operational. The sodium polysulfide melt which results from the chemical reaction of sulfur and sodium is corrosive and proper materials must be developed for its containment at the 575°F temperature that is needed to maintain the electrodes in a liquid form. Thermal insulation and careful control of the temperature must be provided. Inexpensive processing methods for the manufacture of the ceramic have not yet been developed. Although the initial work indicates that none of these problems are insurmountable, we have a long way to go to make this a commercial system.

Figure 6 compares the performance of an internal combustion engine with an electric vehicle equipped with the type of sodium sulfur battery that will meet our objectives. You'll notice that for a comparable performance, as determined by the acceleration, a range can be achieved that is at least as large as that of an internal combustion engine with a normal-sized tank of gasoline.

City Vehicle-Performance
(3200 Lb. Gross Wgt.)

	Electric Drive (Sodium Sulfur Battery)	ICE
Payload (Lbs.)	300	800
Motor	30 hp.	2.3L w/Auto Trans.
Range Per Charge (Miles)		
.20 mph	483	273
.City Driving	280	233
Acceleration		
Distance in 10 Sec. (Ft.)	365 365	373 373

Figure 6

An estimate of the operating cost of this vehicle is given in Figure 7.

City Vehicle-Operating Costs
(3200 Lb. Gross Wgt.)

	Electric Drive (Sodium Sulfur Battery)	ICE
Motor	30 hp.	2.3L w/Auto Trans.
Fuel Cost (c/Mi.)	1.0*	1.4*
Operating Cost (c/Mi.)	1.7	2.1
Total Vehicle Cost (c/Mi.)	8.2	5.6

*Taxes not included

Figure 7

Although the operating cost per mile seems to compare favorably with that of the internal combustion engine, the total vehicle operating cost per mile in city driving will be higher because we expect the cost of the electric motor controller and the sodium sulfur battery system to continue to be higher than the cost of an internal combustion engine.

Since the cost figures of operating an internal combustion engine are taken from Department of Transportation (DOT) data showing averages for the past ten years, they don't reflect recent increases in the cost of gasoline and, therefore, must be considered low. Similarly, the cost of electricity is only an average. Again, to aid in the comparison, taxes are removed from both the cost of gasoline and electricity.

We are optimistic about the potential of the sodium sulfur battery. Its successful application to an electric vehicle would provide performance in terms of range, durability and operating costs that would compete favorably with the present-day internal combustion system. But the electric vehicle still will have many deficiencies.

First, the payload would be less than that of the gasoline-powered vehicle simply because we see no way for the energy density of the battery to be brought up to that of gasoline. This would mean that electric cars could accommodate fewer passengers than would be the case for the same gross weight vehicle powered by an internal combustion engine. Providing auxiliary functions, such as heating and air conditioning, will degrade the overall performance of the electric vehicle more than the internal combustion engine vehicle.

The National Science Foundation, through its program of Research as Applied to National Needs, recognized that the battery is a vital sub-element in a transportation system involving electrical propulsion and in electric peak power storage.

In an effort to expand the research in this critical area, it awarded a contract to Ford Motor Company in June of this year to pursue the application of the sodium sulfur battery, as one means of attacking the energy crisis.

Objectives of the research project are to:

. Develop a better understanding of the interaction of sulfur and sodium at the surface of the ceramic

. Determine the optimal properties for the conductive ceramic, and

. Develop low-cost techniques for mass production of that ceramic

This basic understanding is to be translated into prototype cells that will be tested under realistic conditions. The contract was undertaken as a joint project between Ford Motor Company in Dearborn, Mich., and two major universities — the University of Utah in Salt Lake City and Rensselaer Polytechnic Institute in Troy, N. Y. Work on the project is under way in laboratories at all three locations. Close coordination is maintained through frequent meetings, and a senior member of the Ford group is spending 1974 at the University of Utah working with them in their research. Members of the Rensselaer Polytechnic Institute group are expected to spend the summer months at the Ford laboratory. Every effort is being made to assure close interaction between the various activities. We feel that students and faculty are a vital part of this research effort.

We believe this interaction between a major government agency, the academic community and an industrial laboratory offers great promise of developing a new technology that will benefit a number of problem areas for a wide range of energy users. I would like to close by spending just a moment on this point. We are appalled at the recent popular and technical press articles which suggested that government and industry and universities cannot work together successfully for the common good without be ng improperly influenced or biased by each other. This suggestion is contrary to the long tradition of objective scientific research and in view of today's critical energy problems, should not even be entertained.

It is imperative that all scholars and technicians who can contribute to solving the crisis confronting us employ their talents and resources to attack the problem effectively. I am convinced that the most efficient way to accomplish this is through joint programs in which each participant presents his analysis of the problem to his fellow participant and thereby shares the responsibility for finding the solution to the tough problems we face. Time is too short and the problems too severe to quibble about the possibility of one scientist being improperly influenced by another's thinking.

No one group has all the talent or the complete range of experience to produce the results so urgently needed. When the divergent views of how to solve critical applied problems are expressed in the research and early development phases, significant results can be achieved. Cooperative research — in which the best minds of our universities and industry are brought together with government agencies to work on common problems — is not only a viable but an essential part of solving our energy problems.

It is our fervent hope that political considerations will not preclude the development of fruitful interactions among industry, university and government, for we believe this is a highly productive force that can make a concerted attack on the major applied problems that are critical to our nation's future well-being.

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Mr. SYMINGTON. Thank you, Mr. Brown, and thank you, Mr. Jensen.

Our final witness represents General Motors Corp. He is Mr. Ernest S. Starkman and is vice president, environmental activities staff. He joined General Motors in 1971 after many years on the faculty at the University of California at Berkeley. Mr. Starkman has had many consulting positions with the California and Federal Governments and is the author of more than 100 technical papers on automotive engines and related subjects.

Mr. Starkman is accompanied by Dr. William G. Agnew, technical director of GM's research laboratory.

We welcome both of you, gentlemen. You may proceed with your statement.

[A biographical sketch of Mr. Starkman follows:]

ERNEST S. STARKMAN

Ernest S. Starkman, Professor Emeritus, University of California, Berkeley, was elected vice president of General Motors in charge of the Environmental Activities Staff effective April 1, 1971.

The Environmental Activities Staff, created at the time of Mr. Starkman's appointment, concentrates its efforts on the performance of GM products in the environment.

Under Mr. Starkman's jurisdiction are automotive safety engineering, automotive exhaust emissions and product assurance. He also coordinates activities relating to industrial air and water pollution control.

Immediately prior to joining GM, he had been professor of mechanical engineering, University of California, Berkeley. The title Professor Emeritus in the Department of Mechanical Engineering, Berkeley Campus, was conferred on Mr. Starkman effective April 1, 1971.

He also was assistant vice president for the Statewide University, and before that he had been chairman of the Thermal Systems Division of the College of Engineering.

Mr. Starkman is nationally known for his research work in thermodynamics, combustion and pollution.

Born on October 8, 1919, at Los Angeles, Calif., he graduated from the University of California, Berkeley, in 1942 with a bachelor of science degree in engineering and received his master of science degree there in 1945.

He held positions in private industry as an employe and a consultant, as well as numerous teaching and administrative positions at the University of California, Berkeley, before becoming a professor there in 1960.

He is the author of more than 100 technical papers on engine fuels, lubricants and combustion, and received the Society of Automotive Engineers' Horning Award and Medal in 1959 and the Colwell Award in 1968 for presentations relating to engine combustion.

Mr. Starkman recently served on the White House Task Force on Air Pollution and the office of Science and Technology Ad Hoc Panel on Unconventional Automotive Vehicle Propulsion.

He was chairman of the Technical Advisory Committee to the State of California Air Resources Board from 1968–1971, and served as a member of the panel on "The Automobile and Air Pollution," U.S. Department of Commerce. He also was chairman of the Advisory Committee on Advanced Power Systems to the Council of Environmental Quality, and is a member of the Technical Advisory Board of the U.S. Department of Commerce.

He is a member of the Air Pollution Control Association; a Fellow of the American Society of Mechanical Engineers, and the Institution of Mechanical Engineers; member and director of the International Combustion Institute; member and past director of the Society of Automotive Engineers, and member of the American Association for the Advancement of Science.

Mr. Starkman also is a member of the Tau Beta Pi (engineering), Pi Tau Sigma (mechanical engineering) and Sigma Xi (research) honorary societies.

Mr. Starkman is married and the father of four children.

STATEMENT OF ERNEST S. STARKMAN, VICE PRESIDENT, ENVIRONMENTAL ACTIVITIES, ACCOMPANIED BY WILLIAM G. AGNEW, TECHNICAL DIRECTOR, ENGINEERING RESEARCH, GENERAL MOTORS CORP.

Mr. STARKMAN. Mr. Chairman, thank you.

You have introduced Dr. Agnew. He is indeed technical director and is in charge of our alternative powerplants research program in the General Motors Research Laboratories.

GM is pleased to have this opportunity to discuss with you the automotive powerplant research programs in General Motors and our view of the role the Federal Government should play in research and development of automotive engines.

Because the powerplant is a crucial component in our principal product, General Motors R. & D. in this area has been both long standing and extensive. Throughout our history we have attempted to produce the optimum engine, carburetors, and other components for the job to be done. The characteristics which today are critical in determining the optimum powerplant are fuel economy, emissions, reliability, effectiveness, that is, the ability to do the job, convenience, cost, and, of course, customer satisfaction.

In addition to developing our own ideas, GM is involved in a major screening effort on hundreds of powerplant concepts which are suggested to us each year. During 1973, almost 900 alternate engine and emission control suggestions from outside GM were evaluated. This included 320 on emission control, 399 on alternate powerplants, and 177 on modifications to piston engines.

We feel that we have an obligation to evaluate the potential of every feasible powerplant for automotive application. If a suggestion can be evaluated on paper by well-established principles and careful analysis, we do so. If experimental programs are required for evaluation, we initiate them. If the experimental research shows promise, we carry on to major hardware development.

We think we have a balanced program in alternate powerplant research. We make contact very early with new concepts, and because of our experience, our facilities, and personnel, we are fortunately capable of evaluating potential quickly. Our people are intimately familiar with all of the requirements for an automotive powerplant having to do with manufacturability, durability, cost, and performance under the wide range of conditions experienced by automobiles.

At the same time our R. & D. people try to give the benefit of doubt to each powerplant concept they evaluate. Corporate management, in turn, has been willing to put up money in direct proportion to the amount of promise which R. & D. people can demonstrate for each of the various alternatives.

In evaluating the potential of various powerplants it is necessary to consider tradeoffs among various critical characteristics. In some instances, such as in the case of emission standards, Government mandates place further restrictions on these tradeoffs.

Subsequent to the enactment of the Clean Air Amendments of 1970 and the adoption therein of very stringent oxides of nitrogen control for automobiles, it was acknowledged by EPA that errors had been made by researchers in determining, first, the levels of oxides of

nitrogen in the ambient air and second, assumed minimum levels of oxides of nitrogen from the standpoint of health effects. I am sure members of the committee are now aware of the existence of these errors, which were principally due to the instruments used for measurement.

Most experts in the field now agree that because of these errors a 0.4 gpm of NO_x control is much too stringent as an automotive limit, both from the viewpoint of health and aesthetics.

The EPA has acknowleged error in establishing the automobile NO_x standard. As recently as last week in his testimony before the Senate Subcommittee on Environmental Pollution, Administrator Russell Train said:

> In our judgment the present statutory requirement for the achievement of a 90 percent reduction in nitrogen oxides emissions from passenger cars is not necessary to meet or maintain ambient air quality standards in most of the nation.

The National Academy of Sciences is undoubtedly considering this factor now as part of their study and subsequent report to the Congress.

This point is important to the discussion today because of its relationship to most of the alternate powerplants in our research program which we will describe today—as well as in the case of the current internal combustion engine. Even though otherwise promising, these alternate powerplants are essentially blocked from consideration as candidates for production by the present statutory 0.4 gpm oxides of nitrogen standard mandated by the Clean Air Act for 1977 and succeeding model years. This unnecessarily stringent and perhaps not even practically attainable emission requirement casts a dark shadow over all alternate and conventional powerplant research and will result in serious waste of resources unless prompt recognition is given to the need for its correction. If Congress recognizes and changes this situation then the potential for a number of alternative engines will be significantly enhanced.

Now let me describe some of the powerplant work which is being carried on at General Motors.

THE PASSENGER CAR DIESEL ENGINE

The passenger car diesel engine is already in public use. Today it can attain the original 1975 statutory standards for HC and CO. There are some footnotes* on this page which give you the emission levels we have attained. It is unable to attain the 0.4 gpm nitrogen oxide standard.

The diesel engine stands out for its high efficiency, among all the automotive powerplants which we are seriously considering today. The diesel's fuel economy is greatest in low-speed, stop-and-go-type driving, although it is reduced in high-speed, interstate highway useage. In addition, the diesel engine utilizes a fuel which requires somewhat less refining than gasoline and would, therefore, offer some, although small, advantages in energy conservation at the refinery. This may be offset, however, by the disadvantage of high

*A GM Opel diesel in a record mo[illegible] car attained HC the following degree of emission control: HC=0.32 gpm, CO=1.69 g[illegible] and NO=1.76 gpm.

sulfur content in diesel fuel, causing higher SO emissions in the exhaust.

Indication from tests using experimental engines are that a passenger car with a diesel engine would produce a fuel savings of about 25 percent in city-suburban-type driving when compared with a gasoline-powered vehicle having the same performance. And I want to emphasize that. Current production versions of the diesel passenger car, generally speaking, apparently have been designed with lower performance—passing, acceleration, and other similar tasks—than gasoline-powered cars in order to recognize and compensate for the weight penalty per unit of power associated with diesels.

The energy conservation characteristics of the diesel engine present a strong incentive to consider it for widespread passenger car application. However, the diesel engine traditionally has had certain other characteristics that make it less desirable for passenger car use from the viewpoint of both customer acceptance and protection of the environment. Increased engine weight, higher cost, and the difficulty of starting in cold weather detract from customer approval. Lack of customer acceptance is shown by the fact that even in Europe, where the diesel has been offered virtually since World War II and where the fuel economy incentive has been much stronger in the past than in the United States, last year only 3 percent, approximately, of the passenger car market was diesel-powered.

In addition, noise, smoke, odor, and particulate emissions still represent disadvantages which pose serious environmental problems if a substantial portion of our passenger car fleet were to be converted to diesel engines.

General Motors, of course, has extensive experience in the production and emission control of heavy duty diesel engines, and Opel, General Motors' German subsidiary, markets diesel passenger cars in quantity in Europe.

We and others are studying ways to further reduce its nitrogen oxide and particulate emissions, and to increase the power-to-weight ratio in order to provide better performance and reduce the cost.

DILUTE COMBUSTION ENGINES

There are a variety of "dilute combustion" engines under study at General Motors. To explain the term, a dilute combustion engine is one which operates with an excess of either air or recirculated exhaust. These engine designs are aimed primarily at reduced emission levels and improved fuel economy. They include conventional spark-ignition gasoline engines which have been modified to operate on extremely lean fuel-air mixtures, jet ignition stratified-charge engines, as referred to earlier in the testimony you heard from Chrysler and Ford, and other types of stratified-charge engines.

Engines of the dilute combustion type have attained, in laboratory tests, emission levels for hydrocarbons and carbon monoxide corresponding to the current 1976 model standards, that is, 0.4 gpm HC, 3.4 gpm CO, and 2.0 gpm NO_x. A footnote** indicates the actual results

**For example, the GM jet-ignition engine concept produced emissions in grams per mile as follows:
Vega (with four-cylinder engine): HC=0.3, CO=2.8, NO_x=1.1.
Impala (with V-8 engine): HC=0.2, CO=2.5, NO_x=1.7.

attained by experiments at GM in a four-cylinder and an eight-cylinder engine. They would appear quite promising except for the statutory nitrogen oxide standard of 0.4 gpm. That standard at the moment has yet to be attained for these types of engines.

General Motors has built approximately 30 prototype engines of the jet-ignition, stratified-charge type, both in 4-cylinder and V-8 configurations. Some of these prototype engines are now undergoing durability tests at our proving ground. These tests are also directed to fuel economy and to giving us more information as to performance with leaded gas. In both cost and fuel economy, these engines appear now to offer promise of equaling the performance of our 1975 model conventional engines with catalytic converters.

Thus the jet-ignition dilute combustion engine appears to constitute a strong competitor to the conventional catalyst-controlled engine and we will continue our development efforts.

However, again, we must await either further development of the engine, or a modification of the NO_x standard, before committing further resources for its production.

As to gas turbine engines, research and development on automotive gas turbines has been carried on at General Motors for over 20 years. The heavy duty gas turbine engine for use in trucks and buses is nearing commercial production. We now have a number of turbine-powered trucks and buses now in the field being evaluated. I might say this is a normal use in buses and in trucks. The passenger car size?

The passenger car size turbine has demonstrated low hydrocarbon and carbon monoxide emissions, and in the past year turbine combustor research has made it possible to demonstrate an experimental turbine which has the ability to meet even the 0.4 gpm nitrogen oxides standards with no exhaust treatment. The results specifically are treated in the footnote*** on page 8. This demonstration is encouraging. But, it has only been possible in the laboratory. The complexities of implementing this to production application with a practical control system remain as problems on which we are now working. Durability testing has not even begun on this type of turbine.

Other major areas in which technological advances are required in order to establish the turbine as a competitive passenger car powerplant include initial cost, throttle response, size and weight—and most significantly, fuel economy.

The fuel economy of experimental turbine passenger cars which we have built to date is not particularly favorable. It is roughly comparable to corresponding piston engine vehicles at cruising speeds of 70 miles per hour or higher. At idle and in low-speed, stop-and-go driving, however, the gas turbine engine currently suffers significant fuel economy penalties.

The major activity on General Motors' passenger car turbine program at the present time is directed toward simpler nitrogen oxide controls, fuel economy improvements, and cost reduction. We believe that considerable progress can still be made in these problem areas.

Electric power vehicles continue to command widespread interest in alternate power plant R. & D. work. Contrary to popular conception, for equal performance it appears that the overall fuel economy for the electric battery car is on the same order as for current gasoline-

***Emission test results were: HC=0.02 gpm, CO=2.4 gpm, and NO_x=0.32 gpm.

powered automobiles. The improved efficiency of electrical components aboard the vehicle is offset by the low efficiency of the battery charging and discharging processes, losses in the long transmission lines from the central power station, and the energy losses of the central power station itself.

It should be understood that the electric battery car alone solves neither the air pollution problem nor the energy problem. For the most part, these two problems are simply transferred from the automobile to the central electric generating station, which provides the energy to keep the batteries recharged.

The sulfur dioxide and particulate emissions of the central electric generating station are, on a pound-for-pound basis, a more serious health problem than emissions from automobiles, according to the National Air Quality Standards. Particulate emissions from utilities also are severe problems.

On the other hand, electric battery vehicles could transfer a portion of our transportation energy requirements from petroleum to coal if central stations were predominantly coal fired, and if coal could be made environmentally acceptable at a reasonable cost. This would offer an advantage in the utilization of our domestic energy resources.

In a restricted transportation role, the electric vehicle may have an important place in our future transportation system. It already serves in golf carts, lift trucks, and onsite people movers. In passenger service, it is most likely to be applied first in small urban vehicles for stop-and-go traffic, where performance and range requirements are moderate. The commercial urban delivery vehicle, downtown shopper, commuter, and "errander" appear technically feasible today with *lead-acid battery technology*; however, the economics of such applications are still uncertain.

In this connection, it must be remembered that when use of such vehicles on the streets is contemplated, as opposed to golf courses, factories, and airport transfer systems, Federal auto safety requirements apply, with a resultant adverse effect on size, weight, and cost.

During the past decade, we have built and tested several experimental electric vehicles at our Technical Center in order to evaluate more fully the advancing technology of batteries, motors, and controls. We have constructed experimental electric vehicles which have contained single and dual battery powerplants, a fuel cell powerplant, and both a.c. and d.c. motor electric drive systems.

The smallest experimental electric vehicle we have built was the GM 512 series. This was a two-passenger, special-purpose vehicle intended for limited transportation. It weighed 1,250 pounds, had a 9-horsepower d.c. motor, 330 pounds of lead-acid batteries, which gave the car a range of 58 miles at 25 miles per hour, and had a capability to accelerate from zero to 30 miles per hour in 12 seconds. (No effort was made in this study to conform to Federal safety standards.)

Results of our experimental electric vehicle evaluations have been reported to the technical community and have provided us with needed information to focus our electric powerplant research and development efforts.

The performance of electric vehicles is a direct function of the capabilities of the battery used as the power source. In the GM Research Laboratories we are developing and improving a number of

batteries which could be used in electric vehicles. These are: (1) lead-acid batteries, which are essentially available now in the proper configuration for use in an urban vehicle of limited range (say, 50 miles) and usually of modest performance (50 mph maximum speed); (2) zinc batteries, which are in the advanced stages of development and would provide higher performance in vehicles for both urban and suburban use (say, up to 100 miles range), including some highway driving (up to 60 mph) and; (3) high-temperature batteries, (for example, lithium-sulphur, sodium-sulphur) which are still in the laboratory stage. These batteries show promise for use in vehicles with up to 200-miles range and which are expected to have even higher top operational speed (from 60 to 80 mph).

The fuel cell also has been studied for electric car application. In this device, the fuel and oxidizer are consumed onboard the vehicle to generate electricity as it is used. This system offers the possibility of rapid refueling and a range equal to that of current vehicles. Pollutant emissions are very low and the efficiency is very good. However, extremely low power output per unit weight and volume, short life, and the unfavorable economics of this device have severely limited its development. GM continues to conduct a fundamental research study of electrode structure and catalysts for fuel cells as a long-range effort.

Rankine cycle engines employing steam as a working fluid were prominent for automobile applications at the start of the century. They lost out to the greater convenience and flexibility, compactness, safety, performance and fuel economy of spark-ignition gasoline engines for passenger cars and trucks, and to diesel engines for some heavy duty truck applications.

GM renewed its studies on steam engines in 1926. Continuous attention has been given to this powerplant over the ensuing years. In 1968 a major effort was mounted to determine if new technology would aid in reviving the steam engine for automotive application. In 1970, General Motors completed two experimental, full-scale steam-powered cars, the SE–124 and SE–101. These were evaluated for emissions and general performance and the results were reported to the technical community.

While emissions were reasonably low, one of the principal Rankine cycle engine problems is fuel economy. For example, reports of a recent California bus experiment indicated that steam powerplants experienced from three to five times more fuel usage than a corresponding diesel-powered bus. Our own SE–101 steam-powered passenger car designed to meet all the performance and comfort of contemporary American passenger cars gave only 3 to 4 miles per gallon in city driving.

Other problems of the Rankine cycle engine include high weight and large size, particularly the heat exchangers for vaporizing and condensing, complexity in the mechanism and controls, cost, water consumption, water freezing, and lubrication.

Although GM's steam cars demonstrated in 1970 did not meet even the current 1976 emission standards, it did appear to us that lower levels might be attained with sufficient development work. In this respect, we have taken note of somewhat better emissions and fuel economy obtained in later experiments, using smaller vehicles, apparently

with different performance and comfort criteria. We are looking forward to a closer examination of the results of tests on these cars.

In the past, one of GM's major research efforts was on the Stirling engine. The Stirling engine is an external combustion engine which operates on a closed cycle much like a steam engine, except that it uses a gas such as hydrogen or helium, instead of water. The engine tends to have a very high efficiency, comparable to a diesel engine, and has the capability of using various fuels. It is also quiet, its major components are durable and its hydrocarbon and carbon monoxide emissions are extremely low. While our efforts showed nitrogen oxide emissions to be high, as with the gas turbine, sufficient research and development effort might bring them down to acceptable levels.

On the negative side, the Stirling engine required a large radiator for cooling. It also tended to be heavy and bulky, and the hydrogen or helium working fluid is difficult to seal for life. It is a complicated and expensive engine, and control of power output during rapid transients, as required in an automotive application, appeared to be a difficult task. Although some of these disadvantages may respond to further research and development, others do not suggest that promise. After more than 10 years of R. & D. on this engine, General Motors has set it aside as not being among the most promising alternates for passenger car use.

Hybrid engine electric powerplants have also been studied at General Motors and we have built two such experimental vehicles. The emissions performance of such systems have turned out to be disappointing. The efficiency losses resulting from repeated rapid conversion of energy from mechanical to electric and back to mechanical form is a handicap. In addition, the cost, complexity, and weight of this system renders it unattractive.

At this time, the leading contender for the automotive powerplant of the near future is the conventional, spark-ignition gasoline engine that we know today, but with improved emission controls. All 1975 model General Motors cars produced for sale in the U.S. market will be equipped with catalytic converters which reduce exhaust emissions to the interim 1975 levels and at the same time permit a significant improvement in fuel economy over 1974 model cars. We are attempting to devise automotive emission controls for the spark-ignition gasoline engine which will reach the still lower statutory hydrocarbon and carbon monoxide levels of exhaust emissions, and systems that will also reach the statutory NO_x level of 0.4 gpm.

The dual catalyst and the closed loop-controlled single catalyst systems thus far appear to be the most promising approaches for gasoline-powered vehicles meeting all the statutory standards. However, both systems are complex and costly and neither has demonstrated adequate durability at the required low emission levels.

The closed loop system is an extension of the system we will use on 1975 models, involving use of a single catalytic converter but including an oxygen sensor in the exhaust. It will optimize catalyst efficiency by controlling the air and fuel entering the engine. The oxygen content in the exhaust will be measured and the data fed back to a computer which signals a change in the air/fuel ratio to the fuel metering system.

The dual catalyst system, as its name implies, uses two converters to control emissions of pollutants: One acts as a reducing catalyst and the

other acts as an oxidizing catalyst. In this dual system, oxides of nitrogen are reduced to nitrogen and oxygen in one converter, while hydrocarbons and carbon monoxide are oxidized to water vapor and carbon dioxide by the other.

Through the use of either of these systems, there is at least some hope of eventually developing one which will meet the most stringent statutory standards, if that evolves to be necessary.

We are pursuing the rotary combustion engine because of its strong advantages in the areas of effectiveness and convenience. This engine is 50 percent smaller and 30 percent lighter than a piston engine of comparable power. This small powerplant in turn can involve a lighter, smaller vehicle structure to support it.

The problem of packaging major components becomes especially significant as overall vehicle size is reduced. Since it is obvious that the passengers and their baggage are not likely to become smaller, less and less space is available for the powerplant as design moves in the direction of smaller vehicles.

Both engine efficiency and exhaust emissions on the rotary engine are subjects of intense development work in General Motors. Public introduction of the engine, now anticipated sometime in the 1975 model year, will take place as soon as this development work permits and the necessary certification and emission testing can be completed. Basic emission control approaches will be the same for this engine as with the conventional piston engine.

What is the result of all this effort to date? We see the strong possibility that some of the powerplants I have discussed will come into use in our future transportation system. We doubt that any one alternate powerplant will sweep the field in the near future.

It appears that the future may see a variety of powerplants in use simultaneously, each fulfilling a specific role, each optimized for the particular vehicle it powers in the particular application that vehicle serves. Perhaps it will also be obvious from the previous discussion that none of the promising alternate powerplants described will solve the energy problems of this Nation. Most of the powerplants discussed have lower efficiencies than those of current engines. The diesel engine, with perhaps a 25-percent improvement in fuel economy, represents the only significant exception among the short run alternatives.

Although none of our R. & D. work, thus far, has created the expectation that emission control or energy problems will be solved by some miraculous new powerplant, you may be assured that a great deal is being done, and will be done in the next few years to reduce automotive transportation energy consumption. These activities, including introduction of new small cars and modifications to vehicle design, should have a significant impact on our Nation's energy problem. Other manufacturers reportedly are taking similar steps.

However, it must again be emphasized that one of the most serious obstacles in our effort to solve these long-range problems is the unresolved problems of an ultimate automotive NO_x standard to replace that which, as a result of a combination of errors, was originally established at a level far too stringent for either need or technology. As long as that error is perpetuated by the 0.4 gpm NO_x standard, progress in the development of an alternate powerplant will be thwarted and resources misapplied.

We have watched closely the advanced automotive power systems activity carried out under the auspices of the Environmental Protection Agency. It is our impression that this program, on balance, has been useful.

While excessive amounts of money may have been spent in areas where answers to questions were already known or on matters which were not crucial to evaluation of powerplant potential, in many instances, Government-sponsored R. & D. has confirmed or supplemented corresponding R. & D. in the industry. We naturally are anxious to pick up any new ideas which might be developed, but we have found little new as yet. Many of the conclusions now being arrived at in the Government program look very much like our own reached several years ago.

The program has, of course, been useful to educate a large number of people in the Government and technical community about some of the intricacies of automotive powerplants, vehicles and manufacturing problems. Because of this development, our relations with those outside the industry have been eased. While this has been useful to us, it is doubtful that such a spinoff benefit to private industry was either contemplated or can constitute justification for the rather substantial public funds expended.

In searching for the best role that Government could play in automotive powerplants R. & D., it appears to us that there has been a neglect of two areas in the present EPA program. First, we believe Government research should concentrate more in fundamental areas. There is a real need today for more work to be done in such areas as combustion, materials, heat exchange, electrochemistry, catalysts and hydrogen generation, and storage. Progress must be made in these areas before competitive alternative powerplants can be built to survive in the marketplace.

We question the need for the Government to develop prototypes of products for ultimate sale in a competitive market. Private industry is better equipped and sufficiently motivated to respond to that phase of the problem. Government research of a basic type, in areas which now represent critical bottlenecks in the industry's efforts on advanced powerplants, would supplement rather than duplicate the efforts of industry and thus make real contributions to progress.

The second area for useful Government R. & D., while not specifically on the issue of powerplants, is directed toward broader aspects of automotive transportation in which the Government should carry the major responsibility. Some of these are issues larger than the automotive industry and involve tradeoffs that should represent value judgments of the public as a whole.

For these reasons, we feel the Government should undertake the broad systems studies—

Integrating vehicles, highways and other transport modes;

Correlating emissions, energy, noise and safety standards;

And evaluating societal attitudes and preferences as they relate to benefit/cost analyses.

Questions of individual preference and need should, of course, still be resolved by benefit/cost decisions made by each person in the free marketplace. We think the automobile industry is equipped to respond to such market trends without Government intervention. How-

ever, those systems problems which require community benefit/cost analyses and decisions logically fall under the aegis of Government, and a large amount of research and development work is needed to make those analyses rational and the implementing decisions wise.

Mr. BROWN. I want to compliment you, Mr. Starkman, for an extremely comprehensive and helpful statement. I want to apologize on behalf of the chairman who did have business which required that he leave. I note that in your comprehensiveness you have already given substantial answers to the questions which I asked of the previous witness such as battery-powered vehicles and their applicability in a situation in which the local government prohibited vehicles, say, in the downtown area.

As I indicated to the other witness, there may be increasing examples of this kind of situation in which the market will be pretty well structured for the type of vehicles, such as electric vehicles, which you have described. That might create the type of market which would make these attractive for the automobile companies to get involved in.

Mr. Milford, do you have questions?

Mr. MILFORD. Just one or two, sir.

On page 7 of your statement you discuss jet-ignition, stratified-charge type engines which you are presently testing and you stated that in both cost and fuel economy, these engines appear now to offer promise of equaling the performance of the 1975 model conventional engines with catalytic converters. Since nonleaded gas is required, would you agree we could make a national savings in fuel and other hydrocarbon products if we would return to the exclusive use of leaded gasoline?

Mr. STARKMAN. We have contracted with an independent organization to make an extensive study on this question as to the extent of the penalty of operating with unleaded rather than leaded fuel. We find that the results reported to us, while still in the direction of a penalty, are not nearly as dramatic as the kind of numbers we find quoted from other places. The latest indication we have would suggest that the penalty in terms of ultimate use of a barrel of crude or the price to the consumer is reasonably small.

By that I mean the numbers come out to something like two-tenths of a cent per gallon for the cost of the gasoline and something like two-tenths of a percent more of crude used to provide the kind of fuels we have planned for and built our engines and we have proposed to produce during the next few years and for as long as it is necessary for us to accommodate the kind of standards we foresee.

Mr. MILFORD. Do you have any idea when the results will be available?

Mr. STARKMAN. They are already in, Mr. Milford. If you would like, we will supply you with a copy of the report.

Mr. MILFORD. I would be very appreciative.

Mr. STARKMAN. We will do it.

HON. JAMES W. SYMINGTON,
U.S. House of Representatives,
Washington, D.C.

DEAR CONGRESSMAN SYMINGTON:

The Subcommittee on Space Science and Applications recently held a hearing on Research on Ground Propulsion Systems. During that hearing General Motors Vice President Ernest S. Starkman was asked about the production of unleaded

gasoline. In response, Mr. Starkman referred to an independent study conducted for General Motors on this subject.

Mr. Starkman has asked me to send you the enclosed copy of that study conducted for General Motors by Arthur D. Little, Inc. and dated December 1973. You will note that the results of that study show:

"For current (1973) operations our results concluded that up to 60% of the refinery gasoline pool could be supplied as lead-free gasoline at 91/83 RON/MON (Research Octane Number/Motor Octane Number) meeting the new, more restrictive volatility requirements with no gasoline yield debit. The increased gasoline manufacturing cost that can be attributed to supplying this special grade was less than 0.5 CPG.'

"Our results also showed that up to 80% of the total gasoline pool could be produced as a lead-free grade meeting present volatility standards with no decrease in total gasoline production volume and at essentially no increased manufacturing cost."

IMPACT OF MOTOR GASOLINE LEAD ADDITIVE REGULATIONS OF PETROLEUM REFINERIES AND ENERGY RESOURCES—1974–80

PHASE I

by

Arthur D. Little, Inc.

Acorn Park

Cambridge, Massachusetts 02140

Contract No. 68-02-1332 Task No. 4

EPA Task Officer: David R. Patrick

Prepared for

ENVIRONMENTAL PROTECTION AGENCY

Office of Air and Water Programs

Office of Air Quality Planning and Standards

Research Triangle Park, N.C. 27711

May 1974

Also enclosed is a copy of a study conducted by Arthur D. Little, Inc., for the Environmental Protection Agency and dated May 1974. The results of this study indicate that:

"Most large, modern, efficient refineries (which represent the major source of supply to the U.S. marketplace), will suffer little penalty from manufacturing lead-free gasoline and the lead phase-down."

If you have any further questions on this subject, please let me know.

Sincerely,

ROBERT E. COLE.

I. Summary and conclusions

In February 1974, the EPA asked Arthur D. Little, Inc. (ADL) to review the effects of the EPA regulations which require the availability of lead-free gasoline and the gradual phase-down of the lead content of the total gasoline pool. The EPA required that preliminary results be reported to the EPA in early April, and the final written report be completed by the end of April, 1974. Although previous studies have been conducted and published for the EPA concerning the problems associated with supplying lead-free gasoline and reducing lead content of gasoline, the EPA felt that this review was needed for the following reasons:

Since the previous studies had been conducted, more recent assesments of the status of mobile source emission standards and lead-free gasoline requirements have become available.

Rapid large increases in crude oil costs and associated product prices occurred recently due in part to increased national energy demand and limited supply. Since refinery processing options are inherently sensitive to costs of raw materials and products, and since these options can not be fully analysed manually without severe oversimplification, the EPA felt that a computer analysis of the impact of the lead regulations incorporating current prices was needed.

Natural gas production has continued to decline since the previous studies. This decline has caused increased substitution of volatiles for this marginal supply with associated increase in LPG prices.

Assessments of results of recent EPA test programs and statements by the automobile manufacturers indicate that the fuel economy increase for catalyst-equipped vehicles will not only be greater than the previous 3.5% penalty due to lowered compression ratios to reduce NO_X emissions and prepare for low-octane, lead-free gasoline but also will approximate the 10% penalty for the total of all of the air pollution controls. This change in fuel economy greatly affects projections of gasoline demand and, thus, refinery operations.

Since the last studies, refinery process unit capacities have increased and refining technology, particularly in the development of superior catalysts for catalytic cracking and reforming, has continued to improve.

Potential crude supply restrictions to domestic refineries, as illustrated by the recent Arab oil embargo indicate the necessity of maintaining the refinery flexibility to vary output product mix to meet seasonal demands, e.g., gasoline and fuel oils.

The intent of this study was to evaluate the effect of lead phase-down and lead-free gasoline scenarios on (1) crude oil requirements to meet projected petroleum product demands (e.g., gasoline, jet fuel, petrochemical feedstocks, (2) associated net energy consumption for refining, (3) capital investment (or strain on construction industry) and gasoline costs, and (4) flexibility of the refining industry to adjust the product mix, particularly to seasonal variations of gasoline and fuel oil demands. To achieve this, three scenarios were evaluated for each year considered:

Scenario A.—No Lead Regulations (minimal presence of lead-free gasoline, 3cc/gal lead maximum in regular and premium grades, and distribution of regular and premium in the gasoline pool assuming no additional automotive emission controls).

Scenario B.—Significant Lead-Free Gasoline Marketing, but with No Lead Phase-Down (increase in lead-free pool, with increased lead-free percentage being proportionally subtracted from premium and regular grades; 3cc/gal lead maximum in regular and premium grades).

Scenario C.—Lead-Free Gasoline with Promulgated Phase-Down (same gasoline distribution as Scenario B but with lead phase-down as promulgated in the December 6, 1973 *Federal Register*).

The scope of this study was to consider the impact of the lead regulations upon the *manufacture* of petroleum products. Additional impacts involved in distributing and marketing lead-free gasolines have been analyzed in previous studies.

The Federal Energy Office (FEO) issued forecasts in mid-December of United States 1974 petroleum product demands in an unconstrained environment. Several possible supply scenarios were postulated and resultant product shortages defined. We have used these estimates of 1974 petroleum product demands as the basic source of our model inputs with only minor adjustments made to reflect more recent data in certain instances.

The results of this overview study indicate that:

Most large, modern, efficient refineries (which represent the major source of supply to the U.S. marketplace), will suffer little penalty from manufacturing lead-free gasoline and the lead phase-down. A key premise is that moderate-octane gasoline (refinery target of 92/84 RON/MON gasoline to allow more than ample margin to ensure minimum octane levels of 91/83 RON/MON) will provide satisfactory performance in post-1974 automobiles. (It is recognized that an overview study of this scope does not address itself to analysis of the specific potential problems of some small or atypical refiners. However, it should be noted that the promulgated lead phase-down schedule does not require compliance by small refiners for the first two years).

Through 1976 there is essentially no crude oil penalty for either B vs. A or C vs. B.

The average crude oil penalty for 1977 through 1980 is 30,000–44,000 barrels per calendar day (B/CD) (.2–.3% of A) for B vs. A and approximately 28,000 B/CD for C vs. B (.1% of A).

Through 1976 there is essentially no net energy input penalty for either B vs. A or C vs. B.

The average net energy input penalty (fuel oil equivalent barrels for 1977–1980 is about 10,000–20,000 B/CD (.1% of A) for B vs. A and 20,000–30,000 B/CD (.1–.2% of A) for C vs. B.

Through 1976 there is essentially no capital investment penalty for either B vs. A or C vs. B.

The average yearly capital investment penalty for 1977 through 1980 is 150 million dollars (1974 dollars) for B vs. A and 220 million dollars for C vs. B. These incremental capital investment figures are extremely sensitive to the process routes selected. Phase II of this study will examine capital investment in more detail, in order to provide further information on this point.

The incremental process unit construction due to the lead regulations is insignificant compared to the construction necessary to meet the growth of overall petroleum product demand.

Through 1976 there is essentially no net economic penalty (cents per gallon of gasoline) for either Scenario B vs. A or C vs. B.

For 1977 through 1980, the average net economic penalty is less than .1 cent/gallon of lead-free gasoline for B vs. A and less than .1 cent/gallon of total gasoline for C vs. B.

There is essentially no net energy input penalty and no loss of flexibility of product yields for either Scenario B vs. A or C vs. B for current refinery capacity limitations.

TABLE I-1.—REFINERY IMPACT OF EPA LEAD REGULATIONS

	Average yearly penalty	
	1974–76	1977–80
Crude (million barrels per day):		
Lead free	0	30–44
Lead phasedown	0	28
Total	0	58–72
Net energy input (FOE million barrels per day):		
Lead free	2	10–20
Lead phasedown	2	20–30
Total	4	30–50
Capital investment ($$10^9$):		
Lead free	0	.15
Lead phasedown	0	.22
Total	0	.37
Gasoline Cost (cents per gallon):		
Lead free [1]	(.02)	.02
Lead phasedown [2]	0	.03
Combined [2]	(.01)	.04

[1] Apportionated over lead-free gasoline production only.
[2] Apportionated over total gasoline production.

TABLE II-1.—GASOLINE GRADE REQUIREMENTS BY PERCENT

	1974	1975	1976	1977	1978	1979	1980
A. No lead regulations:							
Grade distribution percent:							
Premium (100 RON)	40	38	39	40	41	42	43
Regular (94 RON)	58	60	59	58	57	56	55
Lead free (92 RON)	2	2	2	2	2	2	2
B. Lead free with no lead phasedown:							
Percent of pool:							
Premium	37	34	28	22	19	15	11
Regular	56	51	42	34	28	22	17
Lead free	7	15	30	44	53	63	72
C. Lead free with lead phasedown: [1]							
Promulgated lead phasedown, pool average (grams per gallon)		1.7	1.4	1.0	.8	.5	.5
Allowable grams of lead per gallon of leaded gasoline [2]	2–2.2	1.98	1.97	1.74	1.65	1.27	1.66

[1] All models having same weight 2,750 lbs.
[2] Current national average.

OVERVIEW
U.S. REFINING CAPABILITY TO SUPPLY PROPOSED NEW GM MOTOR GASOLINES

report to

GENERAL MOTORS CORPORATION

December 1973

C-75992

Arthur D. Little, Inc.

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I. SUMMARY AND CONCLUSIONS

A. INTRODUCTION

The technical staffs of General Motors Corporation (GM) have devoted considerable efforts toward developing satisfactory methods to meet the proposed 1975/1976 automobile emissions standards. After extensive laboratory and engineering investigations, GM has concluded that the most reasonable approach for U.S. automobiles to achieve the proposed emissions standards is the use of catalytic afterburner devices. Since lead anti-knock additives which are present in most of today's motor gasolines act as poisons to the catalytic devices, it is necessary to consider the implications of requiring lead-free motor gasolines. The new emissions standards could also require significant changes in present motor gasoline volatility, especially to traverse the 30 second engine warm-up period. In order to meet 1975/76 emissions standards, GM has developed and suggested new specifications for motor gasolines which will satisfy the requirements of catalytic afterburner devices as well as early engine warm-up standards. In mid-1973 GM commissioned Arthur D. Little, Inc. (ADL) to conduct an overview study of the U.S. refining industry to determine its ability to respond to these proposed new revisions in motor gasoline specifications.

The scope of this study was to simplify the overall U.S. refining industry with a computer model "composite" refinery representing the major portion of U.S. motor gasoline supply. This simplified model would study the yield and associated economic implications of producing several grades and production levels of special GM gasolines. Accordingly, our basic ADL refinery simulator model was revised to incorporate the GM specifications. We considered two time periods in this analysis – 1973 and 1980 operations. Our model simulating 1973 operations provided the short-term results as restricted by existing refinery capacity limitations while the simulation of the 1980 situation determined the long-term operating and investment cost considerations to provide supply.

B. SUMMARY OF RESULTS

For current (1973) operations our results concluded that up to 60% of the refinery gasoline pool could be supplied as lead-free gasoline at 91/83 RON/MON (Research Octane Number/Motor Octane Number) meeting the new, more restrictive volatility requirements with no gasoline yield debit. The increased gasoline manufacturing cost that can be attributed to supplying this special grade was less than 0.5 CPG.

Our results also showed that up to 80% of the total gasoline pool could be produced as a lead-free grade meeting present volatility standards with no decrease in total gasoline production volume and at essentially no increased manufacturing cost.

When gasoline octane specifications (particularly motor number, which was the limiting specification in all cases of substantial lead-free gasoline production) are increased, there is a rapid loss in production volume and an associated exponential increase in manufacturing cost.

The model results for future (1980) operations were essentially the same as for the current environment. At low octane specifications there were no manufacturing problems in maintaining full supply of lead-free gasolines and only nominal increases in manufacturing cost.

Compared with the 1973 cases, future operations which allow increased processing flexibility produced higher yields of lead-free gasoline at increased octane specifications. However, it was still not possible to meet the highest standards proposed because it is very difficult to increase clear motor octane number with present refining technology.

The results of this study also indicated that as long as octane specifications are maintained at moderate levels, the refining capital investments to produce lead-free motor gasolines are small in comparison with the magnitude of total investments needed to supply the industry's 1980 product requirements. For example, we estimate that production of 100% of the gasoline pool as lead-free 91/83 RON/MON product at existing volatilities will require a total refinery capital expenditure by 1980 of $17.2 billion versus $15.0 billion if the present gasoline grade structure is maintained, or a net increase of about 15%.

Most of the 1980 model runs assumed a delivered cost for imported high sulfur crude oil of $7/barrel. We also made a series of runs at higher crude prices which showed little effect on the differential costs for producing lead-free gasolines.

C. CONCLUSIONS

The results of this analysis are not substantially different from other studies made of this subject. They show that the large, flexible and efficient refineries which supply perhaps 90% of U.S. motor gasoline manufacture will suffer little yield or cost penalties associated with making large volumes of lead-free gasoline at the relatively low octane numbers now being proposed by GM. Of course it has been pointed out many times that simplified, fully-optimized refinery models will simulate operating and blending efficiencies that can not be achieved in the "real" world. However, the sophisticated long- and short-range planning functions of the major oil companies have evolved to the point where optimum profitability programs can be approached, especially when supplemented by product and component exchanges between refineries. Accordingly, we believe that the essential results of this study (i.e., that a 91/83 RON/MON lead-free gasoline at existing volatilities can be produced with minimum yield and economic penalty) are valid.

It is recognized that an overview study of this type, in which the entire U.S. refining industry is combined into one composite model refinery, will result in minimum operating penalties. In order to more closely represent the "real" world, it would be necessary to subdivide the total U.S. into logical refining regions which could be differentiated by crude supply patterns, product demands/specifications, refinery processing options and associated regional capital and operating cost differentials. The results of such a more detailed study would pinpoint possible local problems (such as the U.S. West Coast) and would bring the overall analysis closer to the "real" world situation. We do not believe, however, that the regional analysis would reverse the trends and conclusions noted in this overview.

It should also be noted that the smaller, less efficient refineries operating in the United States under special logistic circumstances would suffer a more severe economic penalty for converting to low-lead gasolines. In addition, several other U.S. refineries producing primarily specialty products such as lubes or asphalts would be similarly penalized. Therefore, before "blanket" nationwide standards are unilaterally adopted to significantly revise U.S. motor gasoline specifications, some recognition should be given of the unique problems that will be experienced by these small refiners.

II. MODEL DATA INPUT

A. CURRENT OPERATIONS (1973)

1. Product Demands/Specifications

The product demand slate required for our simulation of the composite U.S. refining industry in 1973 was developed in the following fashion. We reviewed the 1972 statistics published in the January, 1973 *Mineral Industry Surveys* by the U.S. Bureau of Mines. Table I summarizes the U.S. refinery output for the year 1972 as presented in the referenced survey. We did not include in this tabulation refinery gases and other hydrocarbon streams used in own fuel consumption or catalytic cracking coke. These internal refinery streams are not required as data input to our simulation model but are developed internally by the model to maintain refinery material and energy balances.

Since the purpose of this project was to simulate the composite of those refineries producing the major portion of U.S. motor gasoline, we revised the basic Bureau of Mines data to prepare the input to our simulation model. There are several U.S. refineries which are operated to produce high yields of asphalt and/or lubes and low volumes of motor gasoline. Accordingly, we reflected the influence of these on the U.S. average in developing the simulated product demands from our composite "high gasoline yield" refinery.

Naphtha jet fuel (JP-4) normally contains about 30% of kerosene range boiling material and hence the kerosene jet fuel yield was increased to account for this volume. The naphtha portion of JP-4 was combined with other naphthas for such uses as petrochemical manufacture, BTX, solvents, etc. into one "general" naphtha category. We stipulated in the model that this "general" naphtha blend can only be supplied by full boiling range straight-run naphtha from the crude unit. Since this total amounts to only about 4.4% of the overall refinery output, it was felt that this consolidation was satisfactory. A more rigorous analysis would have treated each of the naphtha product categories separately with associated specifications and allowable blending components.

Two products from U.S. refineries are currently supplied primarily from sources other than domestic U.S. refining. These are LPG and low-sulfur residual fuel oil. Thus we felt it was not necessary that our simulation produce exactly the same historical volume yields of these products but instead allow volume elasticity at prices set by the alternative supply sources. These are LPG from natural gasoline plants (@ 8 CPG) and low-sulfur fuel oil imports from the Caribbean (@ \$4.25/Bbl). However, we did set minimum volume requirements for each of these products at approximately 75% of their historical production levels.

TABLE I

U.S. REFINERY OUTPUT – 1972

Product	MM Bbls	%
Gasoline (Includes Aviation)	2,316	51.1
Jet Fuel – Naphtha	77	1.7
– Kerosene	233	5.1
Ethane	9	0.2
LPG	121	2.7
Kerosene	79	1.7
Distillate Fuel Oil (Includes Diesel)	962	21.2
Residual Fuel Oil	293	6.5
Petrochemical Feeds (Minus Gases)	109	2.4
Special Naphthas	32	0.7
Lubes and Wax	71	1.6
Coke (Market)	67	1.5
Asphalt and Road Oil	163	3.6
Total	4,532	100.0

Source: U.S. Bureau of Mines, *Mineral Industry Surveys*, January 1973.

Table II contains the product demands/specifications for 1973 operations which were used as input into our base case. It can be noted that most of the volume units shown for each product (the sum of these volume units outputs should be approximately 100) correspond to the actual 1972 outputs in the previous table. Since our "model" refinery makes less asphalt than the U.S. industry average, we have increased coke production to reflect the additional conversion of residual fractions to gasoline. Our choice of 25.0 volume units of premium gasoline (which results in 49% premium on total gasoline) was based on statistics provided in the *1973 National Petroleum News Factbook* issue. The percentage of premium sales for the important metropolitan areas in the U.S. are tabulated on page 79 of this publication and when weighted by the number of retail outlets for each area results in 47.2% premium in 1972.

2. Crude Oil Supply

The input to U.S. refineries for 1972 was obtained from the same January, 1973 *Mineral Industry Surveys* by the U.S. Bureau of Mines which was used for obtaining the refinery output shown in Table I. Table III summarizes the U.S. refinery input for the year 1972. Note that the column headed "percent" is based on the 4,532 MMBbls of total products as developed in Table I.

TABLE II

PRODUCT DEMANDS/SPECIFICATIONS
ADL MODEL INPUT – (1973 OPERATION)

Product	Volume Units*	Key Specifications
LPG	Min. 2.0	
Premium Gasoline	26.0	RON-Min. 100, MON-Min. 92 RVP-Max. 10, TEL-Max. 3.0
Regular Gasoline	25.0	RON-Min. 94, MON-Min. 86 RVP-Max. 10, TEL-Max. 3.0
Lead Free Gasoline	1.1	RON-Min. 92, MON-Min. 84
Naphtha	4.4	
Jet Fuel (Kerosene Range)	5.6	Sulf-Max. 0.1, API Gravity-Max. 46
Kerosene	1.7	Sulf-Max. 0.1, API Gravity-Max. 46
Diesel Fuel	5.0	Sulf-Max. 0.2
No. 2 Fuel Oil	16.1	Sulf-Max. 0.2
Low Sulfur Fuel Oil	Min. 4.0	Sulf-Max. 0.5
High Sulfur Fuel Oil	1.0	
Lube Base Stocks	1.3	
Asphalt	2.5	
Petroleum Coke	1.7	
	Min. 96.4	

*To give approximately 100.0 total output

TABLE III

U.S. REFINERY INPUT – 1972

Material	MMBbl	%*
Domestic Crude	3,474	76.7
Foreign Crude	807	17.8
Unfinished Oils	52	1.1
LPG (Butanes)	85	1.9
Natural Gasoline	164	3.6
Plant Condensates	53	1.2
Other	10	0.2
Total	4,645	102.5

*Basis: 4,532 MMBbls Products shown in Table I.

Source: U.S. Bureau of Mines, *Mineral Industry Surveys*, January 1973.

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NPRA Special Report Number 3 entitled *U.S. Domestic Petroleum Refining Industry's Capability to Process Sweet/Sour Crude Oil* indicates that about two-thirds of U.S. domestic crude should be classified as sweet. The same publication indicates that about half of imported crude to the U.S. is sweet.

The refinery raw materials supply which we developed for our 1973 refinery model input is shown in Table IV. Note that the incremental crude oil used to balance the product slate was imported sour crude @ $3.75/Bbl. The availability of purchased natural gas was based on the latest historical information available which was for the year 1971 (Final Summary) published by the U.S. Bureau of Mines on December 20, 1972.

TABLE IV

REFINERY RAW MATERIAL SUPPLY
ADL MODEL INPUT – (1973 OPERATION)

Material	Volume Units*	Price – $/BBL
Domestic Sweet Crude Oil	45.0	——
Domestic Sour Crude Oil	30.0	——
Imported Sweet Crude Oil	12.0	——
Imported Sour Crude Oil	To Balance	3.75
Natural Gasoline	3.5	——
Normal Butane	max. 1.0	3.36
Isobutane	max. 1.0	3.78
Purchased Gas (F. O. E.)	max. 3.5	30¢/MSCF

* To give approximately 100.0 Total Output as defined in Table II.

For our overall average of U.S. refining runs the following crude oils were used to simulate the four basic categories: domestic sweet – Louisiana, domestic sour – West Texas, imported sweet – mixed Nigerian, imported sour – Arabian Light. The composite of these crudes in the proportions made available very closely approximates the average sulfur content and gravity of U.S. crudes charged to refineries as indicated in Table V. We allowed our model refinery to reduce purchases of normal butane, isobutane and natural gas, if profitable, at the price levels indicated in Table IV.

B. FUTURE OPERATIONS (1980)

1. Product Demands/Specifications

Since oil is only one of the major fuels consumed in the U.S., it is necessary to first determine what role oil will play in the total energy balance in 1980. To

TABLE V

CRUDE QUALITIES – ADL REFINERY SIMULATION 1973

Crude Type	% Volume	Gravity – °API	Sulfur – % w
Louisiana	45	36.2	0.2
West Texas	30	33.2	1.7
Mixed Nigerian	12	28.5	0.2
Arabian Light	13	34.5	1.7
Average of Above		34.1	0.7
1971 U. S. Average Production*		32.5	0.7

* Derived from data given in "Giant Fields" section of the *International Petroleum Encyclopedia.*

do this we divided the U.S. energy market into five primary energy consuming markets: residential/commercial, transportation, utilities, industry, and miscellaneous. For our base year (1972) we then determined the Btu's of energy and the primary form (coal, oil, natural gas, hydro-nuclear) each consuming market used. Applying the same growth rates assumed in the National Petroleum Council's "Initial Appraisal"[1] and in its intermediate demand case in the "U.S. Energy Outlook,"[2] we projected the total Btu's which would be required in 1980 by each consuming sector. Having forecasted the total number of Btu's required by each consuming sector, we then estimated the percentage share of the total Btu's in each sector which would be fulfilled by oil.

We actually determined a range of oil demands by examining the impact of three scenarios on the total demand for oil. Each of the three cases makes assumptions about the position which oil will hold in each market relative to oil's 1972 share. For example, in one case, which was designed to simulate a situation of maximum oil demand, oil was assumed to hold its 1972 position and absorb all of the growth in the residential/commercial, transportation and industrial markets. In the utility market, oil was presumed to not only maintain its share and assume all growth, but was assigned to replace all natural gas currently consumed by that sector. The other two scenarios explored a maximum nuclear case (in which oil growth is, therefore, minimal) and a moderate course in which oil participates in growth in energy demand in proportion to its 1972 market shares.

1. National Petroleum Council, "U.S. Energy Outlook: An Initial Appraisal 1971-1985," November 1971.
2. National Petroleum Council, "U.S. Energy Outlook," December 1972.

The product demand input to our ADL refinery model for 1980 base case operations is shown in Table VI. All product demands were fixed except LPG (which was allowed to sell above a minimum production level at $8.00 per barrel refinery netback) and low-sulfur residual fuel oil (which was allowed to produce up to a maximum of 15% volume at $9.00 per barrel). The residual fuel oil has a heating value approximately double that of LPG so there is a substantial "form" value premium for the LPG.

We considered two basic scenarios for grade distribution of the total gasoline pool in the base case. Scenario I assumed that there would not be widespread conversion to automotive engines equipped with catalytic afterburners requiring lead-free gasoline and that the present gasoline grade distribution would change only slightly to 47% premium gasoline and 6% lead free. Scenario II assumed that a major shift to a lead-free 92 octane gasoline would occur for 1975 and later models and that by 1980 the base case overall gasoline output would consist of 3% premium and 41% lead-free 92 RON.

This specification (92 RON) was chosen to represent the low lead grades currently being supplied and should not be considered a formal recommendation by GM.

We anticipate a reduction in petroleum coke production concurrent with the increased profitability for producing low-sulfur oil.

TABLE VI

PRODUCT DEMANDS
ADL MODEL INPUT – (1980 OPERATION)

Product	Volume Units*
LPG	Min. 2.5
Gasoline	40.1
Naphtha	3.0
Jet Fuel (Kerosene Range)	7.5
Kerosene	2.6
Diesel Fuel	5.0
No. 2 Fuel Oil	20.0
Low-Sulfur Fuel Oil	Max. 15.0
High-Sulfur Fuel Oil	1.0
Lube Base Stocks	1.3
Asphalt	2.5
Petroleum Coke	1.2

*To give approximately 100.0 Total Output.

2. Crude Oil Supply

The refinery raw material supply which we developed for our 1980 refinery model input is shown in Table VII. We assumed that the domestic crude oil total would approximate 50% of the crude slate, of which 60% was sweet. Again, imported sour crude oil was the incremental crude supply and in 1980 it was assumed to cost $7.00 per barrel, delivered. Although this may superficially appear low, this is a high-sulfur, poor quality crude oil and other crude oils which are valued in parity with this reference crude had much higher values (and presumed prices) calculated by the 1980 base case. The domestic sour crude oil (West Texas) was valued at $7.25 a barrel, the domestic sweet crude oil (Louisiana) was valued at $8.30 a barrel and the imported sweet crude oil (Nigerian mixed) was valued at $8.35 a barrel. However, to test the sensitivity of lead-free gasoline economics to crude price, we made some runs at higher crude prices ($10 a barrel for delivered Arabian light).

TABLE VII

REFINERY RAW MATERIAL SUPPLY
ADL MODEL INPUT – (1980 OPERATION)

Material	Volume Units	Price – $/Bbl
Domestic Sweet Crude Oil	30.0	
Domestic Sour Crude Oil	20.0	
Imported Sweet Crude Oil	10.0	
Imported Sour Crude Oil	To balance	7.00
Natural Gasoline	2.0	
Normal Butane	Max. 1.0	8.00
Isobutane	Max. 1.0	8.50

We anticipated that normal and isobutane purchase prices would be consistent with the refinery netback price for LPG (mostly propane) and reflect market premiums for these products due to decreased availability of natural gas liquids. Thus, we allowed our 1980 refinery to purchase normal butane and isobutane at prices of $8.00 per barrel and $8.50 per barrel respectively. Propane (@ $8.00 per barrel) has a lower heating value than either normal butane or isobutane. We assumed that the availability of natural gasoline would decrease from 3.5% volume to 2% volume and that purchased natural gas would no longer be available for refinery use.

III. MODEL RESULTS

A. CURRENT OPERATIONS (1973)

1. Base Case

The optimized refinery material balance for the base case is shown in Table VIII. It can be seen that the model did not find it economically attractive to process as much incremental crude oil (imported sour at $3.75 per barrel) and make as much LPG (at 8 CPG) and low-sulfur residual fuel oil (at $4.25 per barrel) as the 1972 actuals.

TABLE VIII

REFINERY MATERIAL BALANCE
1973 BASE CASE
VOLUME %

Intakes	1973
Domestic Sweet Crude Oil	46.42
Domestic Sour Crude Oil	30.94
Imported Sweet Crude Oil	12.38
Imported Sour Crude Oil	5.54
Natural Gasoline	3.61
Normal Butane	1.03
Isobutane	1.03
Purchased Gas (F.O.E.)	3.61
Total	104.56

Outturn	1973
LPG	2.06
Premium Gasoline	25.79
Regular Gasoline	25.79
Lead-Free Gasoline	1.13
Naphtha	4.54
Jet Fuel	5.78
Kerosene	1.75
Diesel Fuel	5.16
No. 2 Fuel Oil	16.80
Low-Sulfur Fuel Oil	4.70
High-Sulfur Fuel Oil	1.03
Lube Base Stocks	1.34
Asphalt	2.58
Petroleum Coke	1.75
Total	100.00

A simplified refinery flow diagram of the processing sequence selected for the base case is given in Figure 1. A detailed description of the model operation and the development of technical refining data used as input for these runs is given in the appendix to this report. Of special interest is the variation of feed capacity limitations for conversion units, such as catalytic cracking and reforming, as a function of processing severity. For example, if it is desired to increase the catalytic cracker conversion from 65 to 85% on an existing unit at feed capacity, it is necessary to reduce intake by 5%.

Table IX provides a comparison between the processing unit intakes selected by the model for the 1973 base case operation and the individual unit capacity limits reported in the April 2, 1973 *Oil and Gas Journal*. Our optimized composite refinery checked fairly well against existing unit limitations. There are some refineries which charge atmospheric crude distillation column bottoms directly to thermal operations instead of via vacuum distillation. This is one reason why our vacuum distillation intake is slightly higher and thermal intake lower than industry capacity. The catalytic reforming intake required by the model was lower than industry capacity available, reflecting the more efficient octane improvement inherent in a completely optimized system. It also reflects the simplification of treating BTX manufacture only as a debit from the general naphtha pool and thus not requiring reforming capacity to produce. We estimate that including BTX with reformate production would add 2 to 3% to reformer intake. Since we are examining delta yield and economic effects from an optimized base case, the deviation caused by this simplification is not significant.

TABLE IX

1973 BASE CASE REFINING SIMULATION
U.S. PROCESSING CAPACITY

Unit	Capacity*	Model Result
Crude Distillation	100.0	100.0
Vacuum Distillation	36.8	39.7
Catalytic Reforming	26.6	18.5
Catalytic Cracking	32.2	30.6
Hydrocracking	6.2	5.1
Alkylation	5.8	6.3
Thermal Operations	10.3	5.1

*Basis *Oil and Gas Journal* – April 2, 1973.

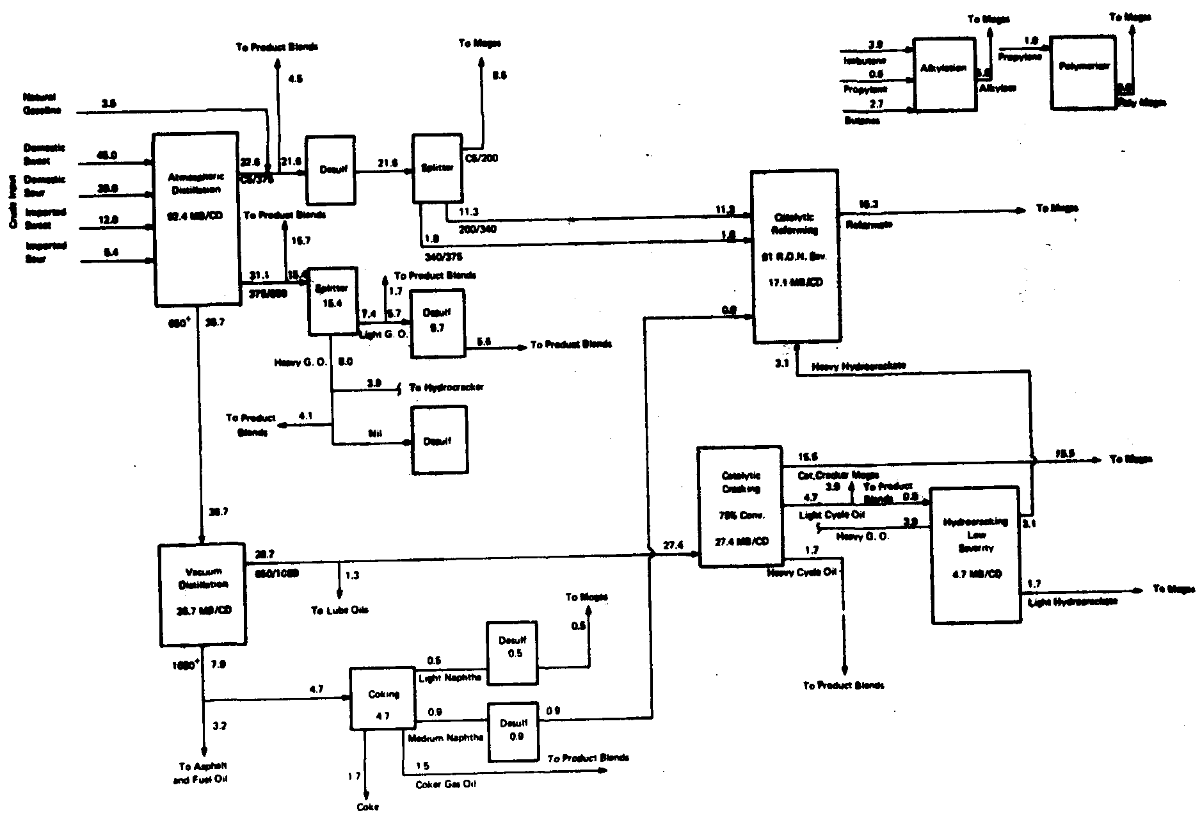


FIGURE 1 1973 BASE CASE
ALL VOLUME FLOWS IN MB/CD

2. Parametric Runs

The processing unit capacities calculated as required for the optimized base case refinery were then submitted as data input to limit maximum processing unit intake availabilities for all subsequent 1973 runs. We then systematically increased the yield and octanes of lead-free gasolines both with the new proposed volatility specifications and with existing volatilities. The proposed new GM volatility specifications are:

10% evaporated, ° F	140 ± 10
50% evaporated, ° F	200 ± 10
90% evaporated, ° F	300 ± 10
endpoint, ° F	365 maximum
Reid vapor pressure	8-9

The first set of parametric runs consisted of increasing volume yields of a 91/83 RON/MON unleaded gasoline at the proposed new GM volatilities. The gasoline yield penalty associated with producing this grade of gasoline is presented in Figure 2. It can be seen that up to 60% of the total gasoline pool can be produced as a lead-free 91/83 RON/MON *new* volatility product with no yield debit in our simulated refinery. Processing unit intakes were limited to base case availability (with appropriate capacity adjustments made for changes in operating severity). When the entire refinery gasoline pool is produced as a lead-free GM grade, gasoline output was reduced to 90% of the base case level. If, however, the gasoline is allowed to meet *existing* volatility specifications, then up to 80% of the pool can be produced as lead-free grade with no yield penalty. When the pool was increased to 100% lead-free, nearly 99% of base case gasoline production can be maintained.

Figure 3 provides a simplified flow diagram of the case producing 100% of the gasoline pool as a lead-free grade, but at existing volatility specifications. It should be noted that this case produced 99% volume of the total base case gasoline. The key processing differences were an increase in reforming severity to 97 clear RON from 91 (at a reduction in feed rate from 17.1 to 16.7 MB/CD) and an increase in catalytic cracker conversion from 78 to 85% (at a reduction in feed rate from 27.4 to 26.9 MB/CD).

Figure 4 provides the economics associated with the parametric case of increasing lead-free gasoline yield at 91/83 RON/MON. The base case operation indicated that a 13.8 CPG composite refinery gasoline netback was required to cover all raw material costs, refinery operating expenses, and a 20% before-tax return on capital investment, less by-product credits. For all parametric cases the individual unit raw material costs and by-product credit price levels were kept constant, including the balance of the conventional motor gasoline pool. All

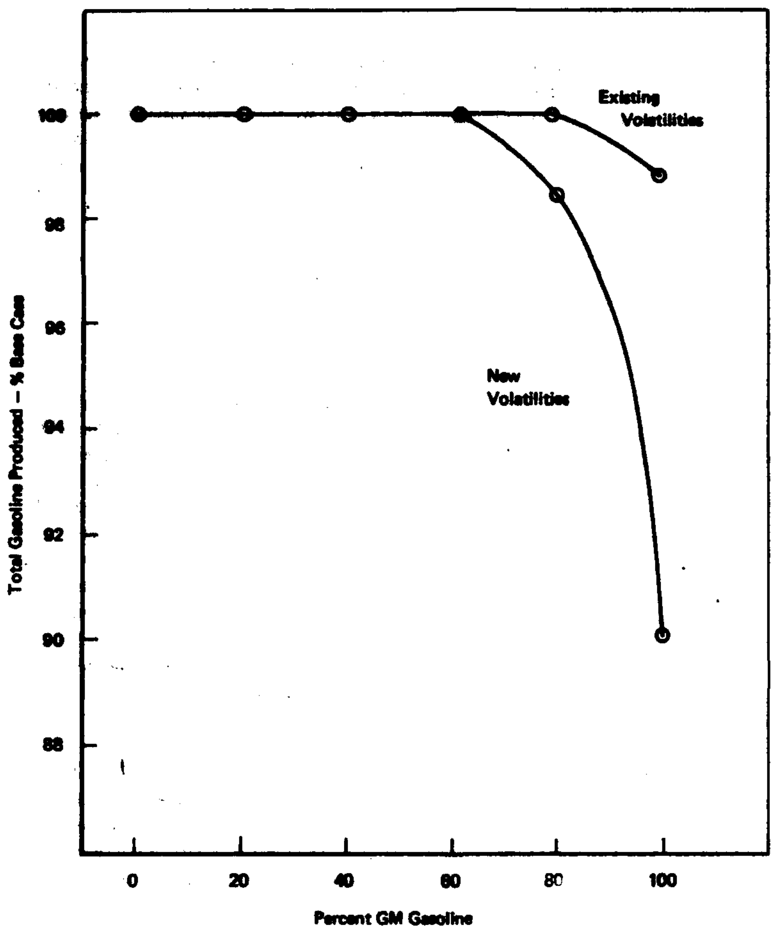
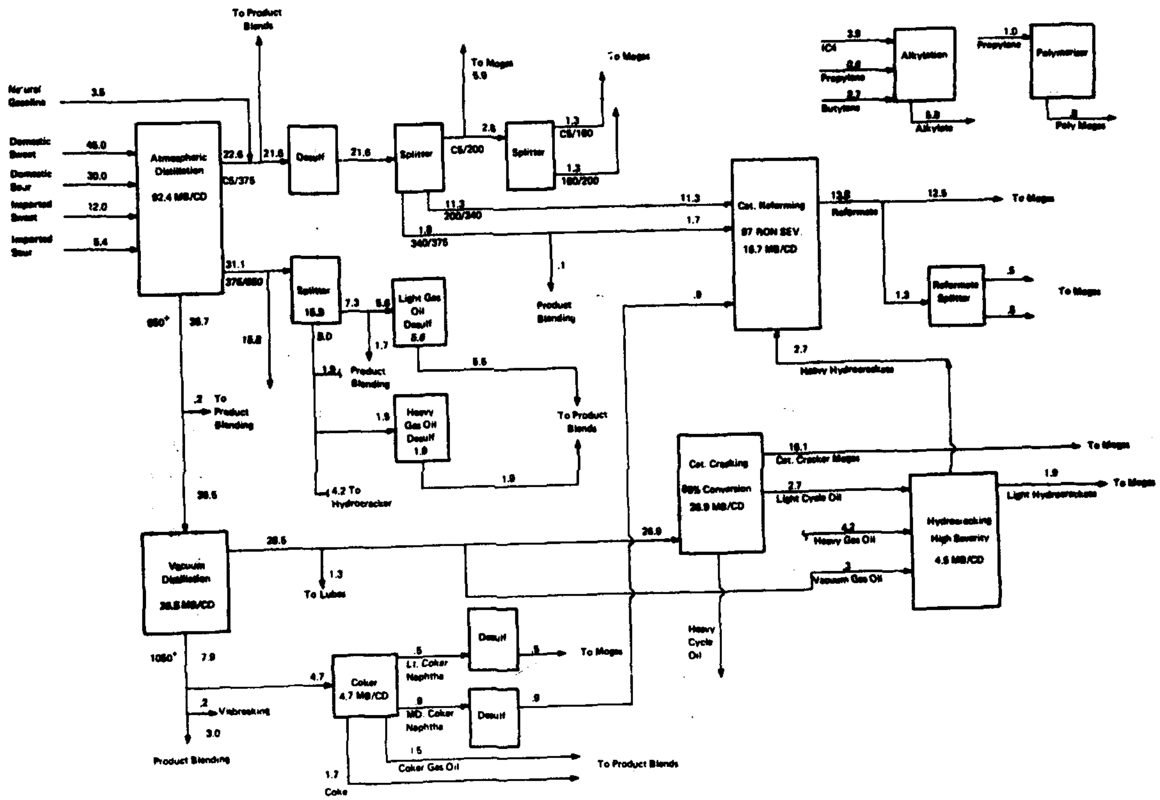


FIGURE 2 1973 OPERATIONS – TOTAL GASOLINE PRODUCTION VERSUS PERCENT GM GASOLINE
(Existing and New Volatilities – RON—91/MON—83)



Note: 99% Volume Requirement of GM Mogas Produced

FIGURE 3 1973 – 100% GM MOGAS
GM SPECS – 91/83 RON/MON – EXISTING VOLATILITIES

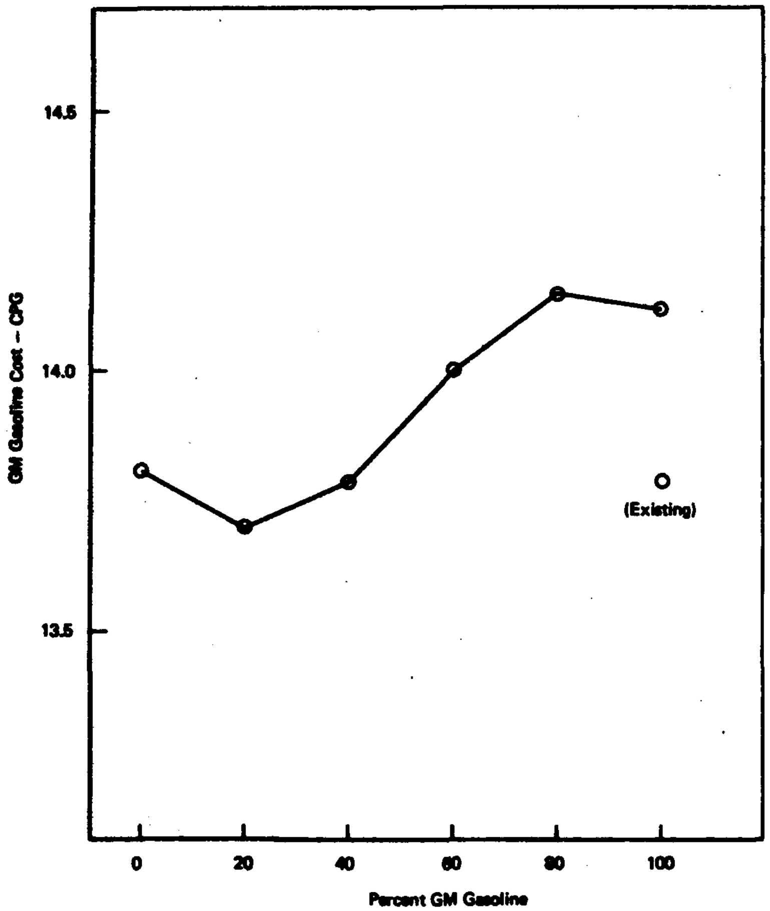


FIGURE 4 1973 OPERATIONS – GM GASOLINE COST VERSUS PERCENT GM GASOLINE (New Volatilities – RON–91/MON–83)

credits or debits due to changes in refinery purchased raw materials, refinery capital and operating costs, and by-product production levels were reflected in the value of the new GM gasoline grade.

It should be noted that the initial production volume of lead-free gasoline can be produced at less cost than the balance of the conventional refinery pool. This is because of the wide variations in octane/lead susceptibility among the various gasoline blending components. The optimization of refinery reforming operations/lead additions is determined using the average susceptibility of each product grade. When it is desired to make a small percentage of the pool as a separate lead-free grade and use those components least susceptible to lead additions in this grade, there is an economic benefit. However as expected, when the percentage of lead-free grade increases to about 40%, there is an economic debit associated with producing this product. The slight decrease in gasoline cost between the 80 and 100% levels reflects the reduction in gasoline yield due to processing unit bottlenecks rather than a discontinuity in fundamental supply economics.

We have also shown in Figure 4 the cost for producing 100% unleaded gasoline at existing volatilities, which is essentially the same as the base case cost. The increased refinery processing required to raise the pool clear motor octane number from the base case level of 81.6 to 83 is essentially offset by eliminating the lead additive costs.

The conclusions from this set of parametric runs should not be surprising since similar studies have indicated that there are no severe economic or yield penalties associated with producing lead-free gasolines of about the 91/83 RON/MON level.

Another significant point is that the base case leaded gasolines each had about an 8 octane sensitivity (i.e., RON minus MON). However, when lead is removed from the refinery pool, motor octanes decrease faster than research and thus become the limiting specification. For example, in catalytic reforming, increasing severity to raise clear research octane number 12.0 units will increase clear motor octane number only 7.9 units. Thus, in order to meet the 83 MON at 100% GM gasoline and the new volatilities, a research octane number of 92.7 (or a "giveaway" of about 1.7 research octane units) was required. This phenomenon continued throughout the remainder of the 1973 and 1980 runs.

In the next set of parametric runs, 30% of the total gasoline pool was produced as lead-free grades, again at both new and existing volatilities. It was felt that this 30% case was an important scenario to examine in that if new standards are imposed on the U.S. refining industry, it will take about three years before major additions to processing units can be made. Thus up to 30% of the pool

could be required as the new grades from refineries which are still limited by existing processing capability. For these runs we successively increased octane numbers from 91/83 RON/MON to 99/91 for the unleaded grades. Figure 5 indicates the yield reduction penalty for producing the GM grades as motor octane number is increased. It can be seen that up to 85 clear octane number can be produced at the new volatilities with no yield penalty, while up to 87 octane can be produced at existing volatilities with no yield debit. Figure 6 is essentially the same as Figure 5 except that the entire yield reductions are reflected on the lead-free GM grade rather than the total gasoline pool and thus the magnitudes are more severe.

Figure 7 indicates the gasoline costs for producing the new unleaded grades at the higher motor octane numbers. As expected, there are significant increases in gasoline costs with the higher motor octane numbers.

The last set of parametric runs for 1973 operations was at 100% unleaded gasoline production at increasing motor octane number. Figure 8 shows the yield decline as octane number is increased. For the existing volatility cases, the model could make up to 86 clear motor octane number before becoming infeasible. At the new volatilities, 83 was the maximum clear motor octane number possible. Figure 9 presents the economics for these runs. Increasing clear motor octane number from 83 to 86 at existing volatilities will cost about 2 CPG in the 1973 base case refinery.

Figure 10 shows the simplified refinery processing sequence for producing 30% unleaded gasoline at the new proposed GM volatilities and 97/89 RON/MON. The major differences from the 1973 base case are increases in reformer severity from 91 to 96 and catalytic cracker conversion from 78 to 85. To make 30% of the pool at 365° F max. endpoint (E.P.), the following steps were taken. Reformer feed E.P. was lowered from 375 to 340° F to produce a low E.P. reformate blend stock for the GM grade. Both straight-run and heavy hydrocracked feed stocks were adjusted. A portion of the full range catalytic cracked gasoline was "re-run" to produce a low E.P. blend component.

B. FUTURE OPERATIONS (1980)

1. Base Case

The initial base case run for 1980 adopted Scenario I described in the product demand section (i.e., assuming the continuation of present grade mix of premium and lead-free gasoline within the gasoline pool). For this case the model calculated a composite gasoline netback of 25.26 CPG required to cover raw material costs, refinery operating expenses and capital recovery, less by-product credits.

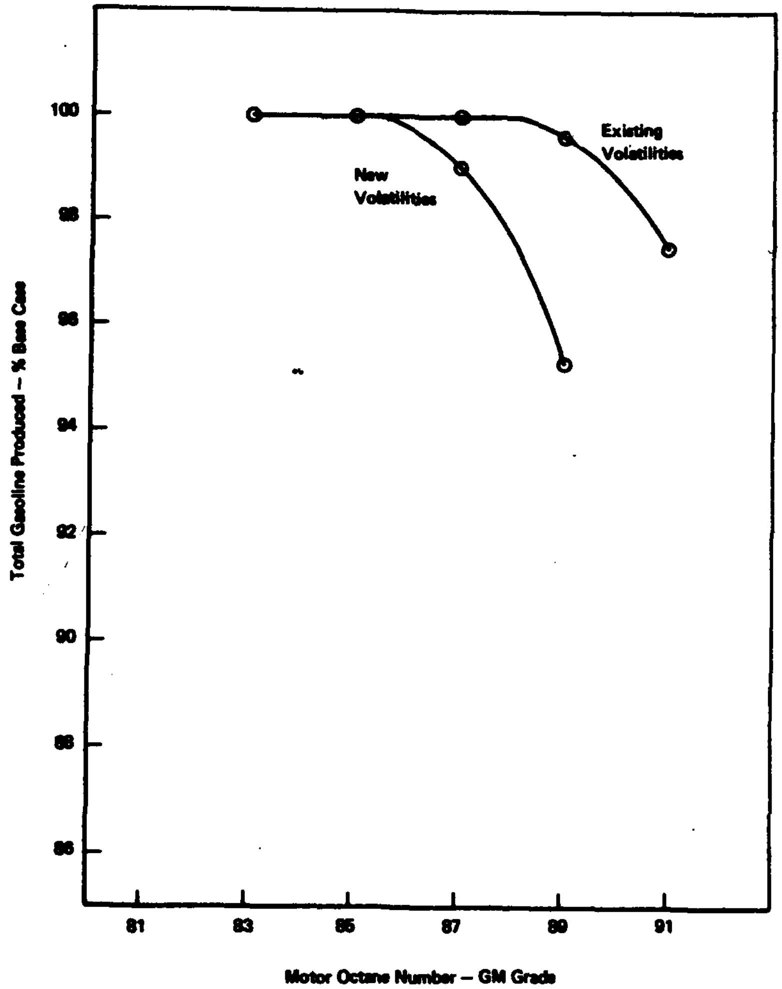


FIGURE 5 1973 OPERATIONS – TOTAL GASOLINE PRODUCTION VERSUS MOTOR OCTANE NUMBER – GM GRADE (Existing and New Volatilities – GM Gasoline 30%)

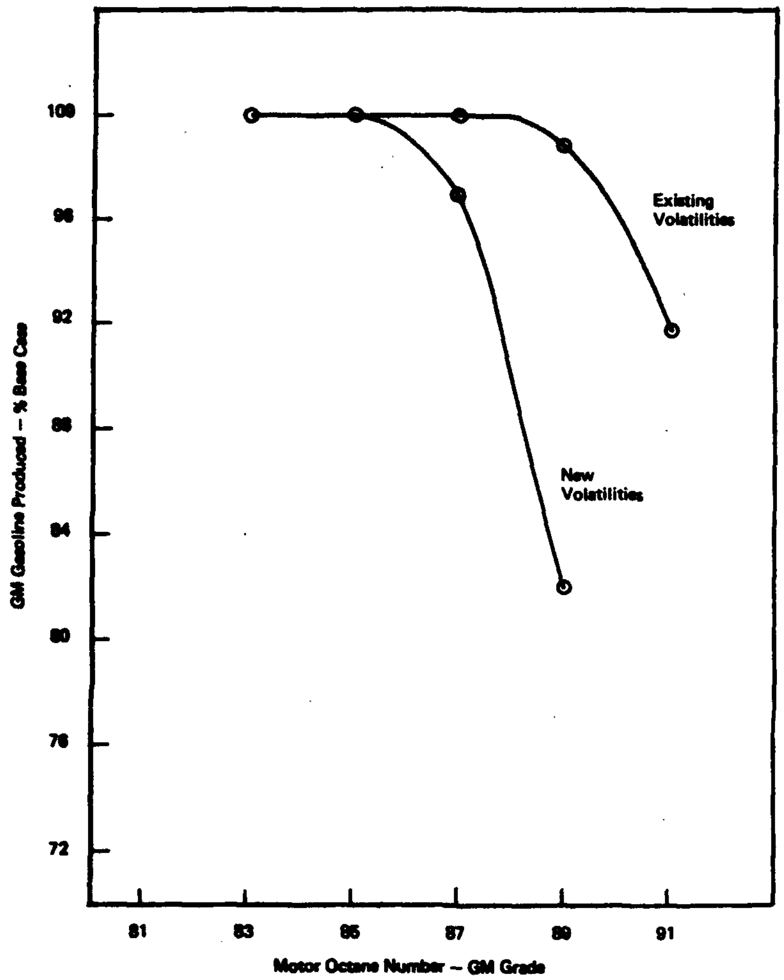


FIGURE 6 1973 OPERATIONS – GM GASOLINE PRODUCTION VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing and New Volatilities – GM Gasoline: 30%)

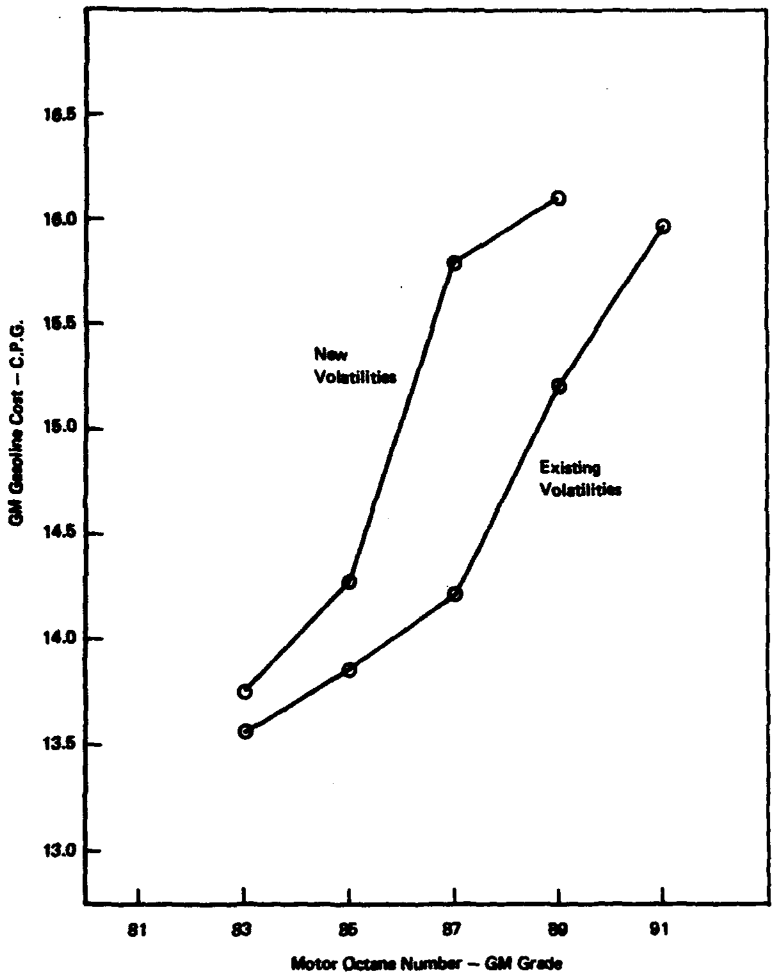


FIGURE 7 1973 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE (Existing and New Volatilities – GM Gasoline: 30%)

36-993 O - 74 - 23

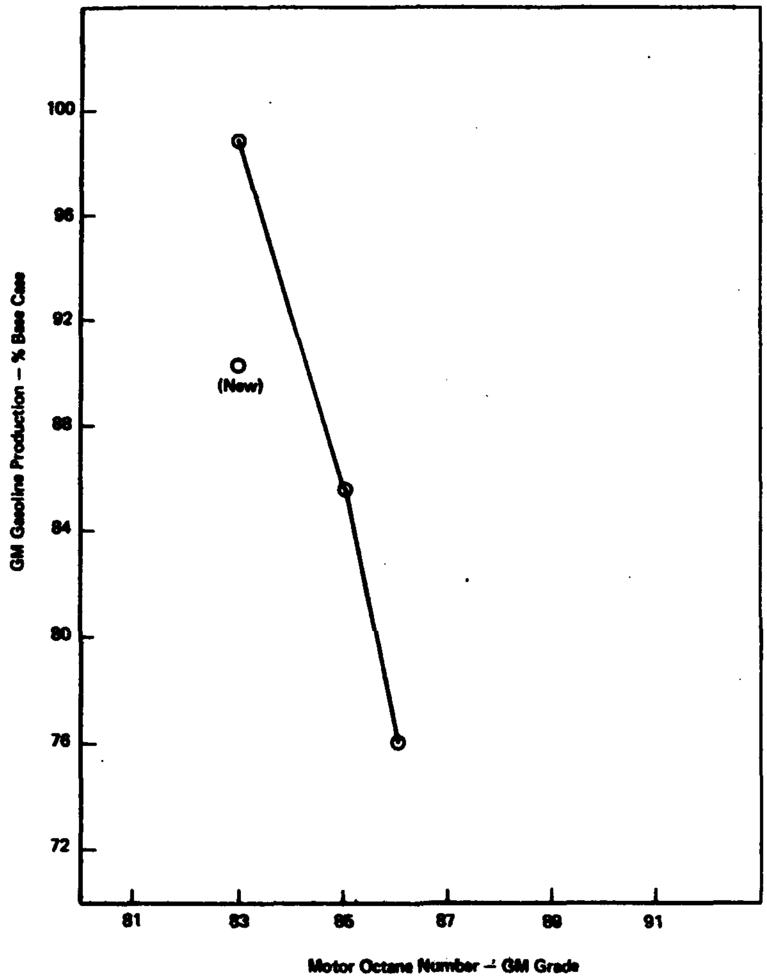


FIGURE 8 1973 OPERATIONS – GM GASOLINE PRODUCTION VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing Volatilities – GM Gasoline: 100%)

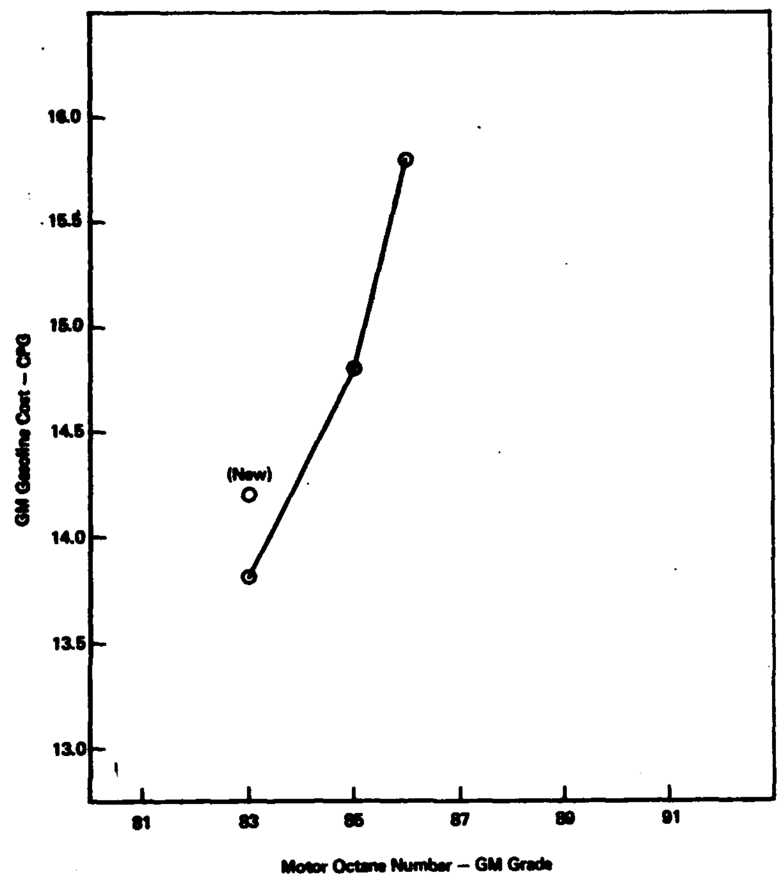
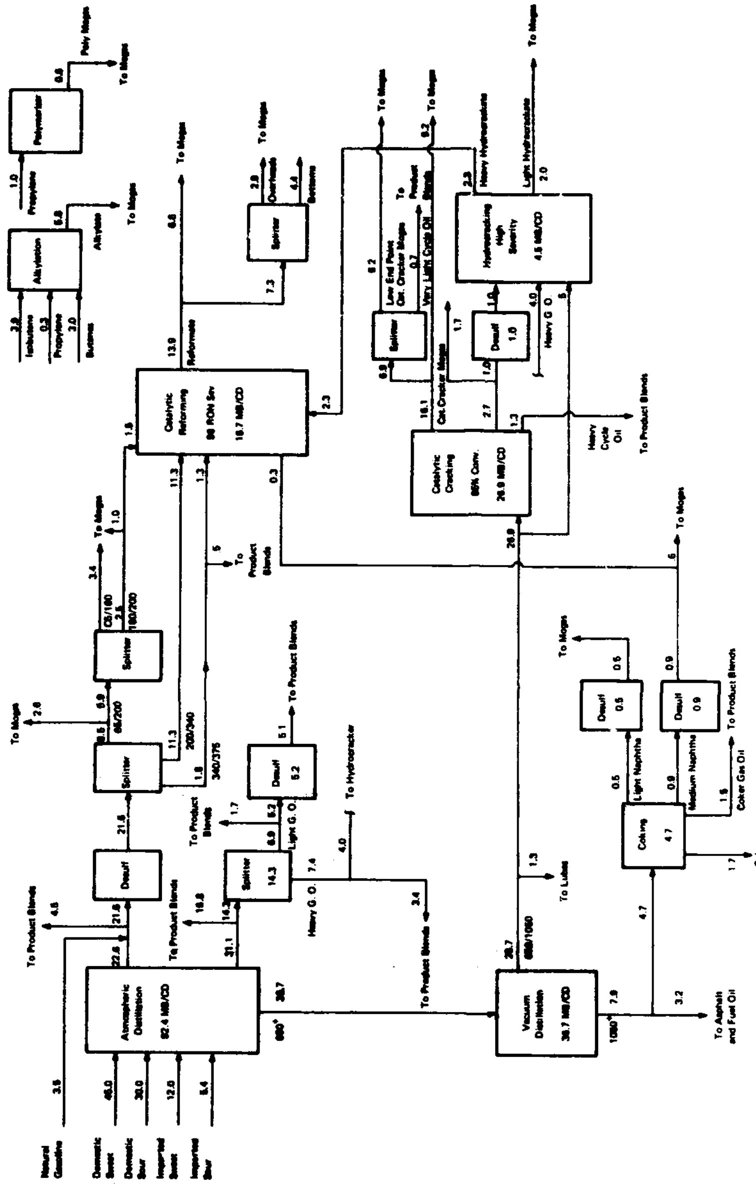


FIGURE 9 1973 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE (Existing Volatilities – GM Gasoline: 100%)



Note: 97% Volume Requirement of GM Mogas Produced

FIGURE 10 1973 – 30% GM MOGAS
GM SPECS – 97/89 RON/MON – NEW VOLATILITIES

The alternative base case as described in Scenario II in the product demand section (i.e., the gasoline pool in 1980 will require essentially no premium gasoline and a high volume of lead-free product) resulted in a composite gasoline manufacturing cost of 25.00 CPG or a reduction of only 0.26 CPG from the other alternative. Since this scenario essentially replaced a leaded 100/92 product with an unleaded 92/84 grade, there was little change in refinery processing. The primary reason for the reduced manufacturing cost of the composite pool was due to the large reduction in purchased lead.

Table X presents the refinery material balance for the 1980 base case under the first scenario. It can be seen that the model found it attractive to produce a higher volume of marginal LPG than the minimum specified, and also to make the maximum allowable volume of low-sulfur residual fuel oil. A simplified refinery flow diagram for this base case is shown in Figure 11. There is a reduction in catalytic cracker intake and conversion versus the 1973 case, but increases in catalytic reforming intake and s. .erity and hydrocracking operations. The higher concentration of sour crudes caused increased distillate desulfurization as well as the introduction of catalytic cracker feed and residual fuel oil desulfurization.

2. Parametric Runs

The first set of parametric runs was made by systematically increasing production of a 91/83 RON/MON lead-free gasoline at both the new and existing volatilities. Allowing flexibility to incorporate new refinery processing equipment, it was possible to maintain 100% of the base case gasoline production at these moderate octane levels for all cases. Figure 12 shows the increased manufacturing cost associated with producing an increasing percentage of lead-free gasoline. As in the 1973 runs, it is possible to manufacture essentially 100% lead-free gasoline at low octanes with no significant increase in cost. Again it should be noted that the motor octane number was the limiting product specification at the high percentage of lead-free supply. For example, in the 100% lead-free gasoline case with new volatilities, the research octane number was 93.6, or a "giveaway" of 2.6 octane units.

Figure 13 shows a simplified refinery flow diagram for producing 100% GM gasoline at 91/83 RON/MON and existing volatility. This case produced exactly the same volume of motor gasoline as the 1980 base case but required an additional 1.2 unit volumes of crude oil. However, there was an offsetting increased production of 1.4 volume units of LPG (the only product outturn allowed to vary). Although the lead-free gasoline consumed more crude oil, an offsetting credit must be given for the increased supply of LPG which carries a premium form value in the marketplace. The significant changes in refinery processing sequence from the base case include a substantial increase in catalytic reforming feed from 22.6 to 27.0 MB/CD and an increase in severity from 95 to

TABLE X

REFINERY MATERIAL BALANCES
1980 BASE CASE
VOLUME %

Intakes	1980
Domestic Sweet Crude Oil	26.97
Domestic Sour Crude Oil	17.96
Imported Sweet Crude Oil	8.99
Imported Sour Crude Oil	49.14
Natural Gasoline	1.80
Normal Butane	–
Isobutane	–
Purchased Gas (F.O.E.)	–
Total	104.86

Outturns	1980
LPG	2.72
Premium Gasoline	20.68
Regular Gasoline	20.68
Lead Free Gasoline	2.79
Naphtha	2.70
Jet Fuel	6.74
Kerosene	2.34
Diesel Fuel	4.50
No. 2 Fuel Oil	17.97
Low Sulfur Fuel Oil	13.48
High Sulfur Fuel Oil	.90
Lube Base Stocks	1.17
Asphalt	2.25
Petroleum Coke	1.08
Total	100.00

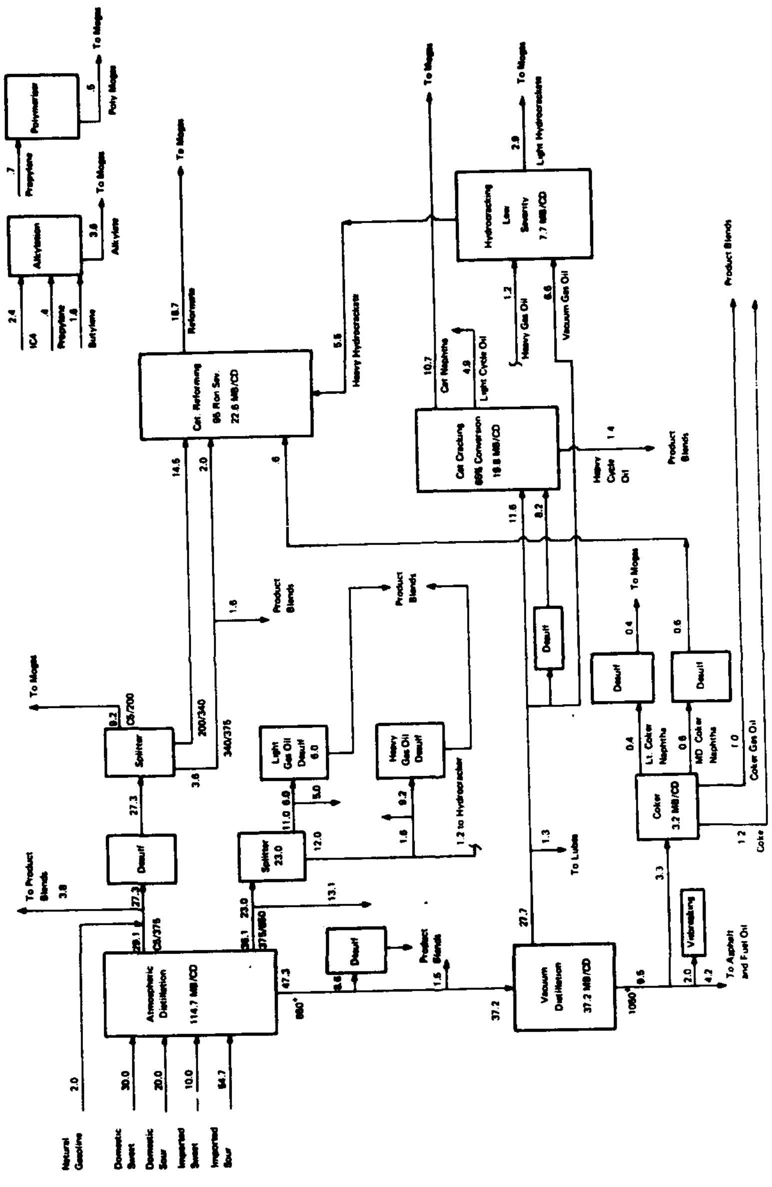


FIGURE 11 1980 BASE CASE
ALL VOLUME FLOWS IN MB/CD

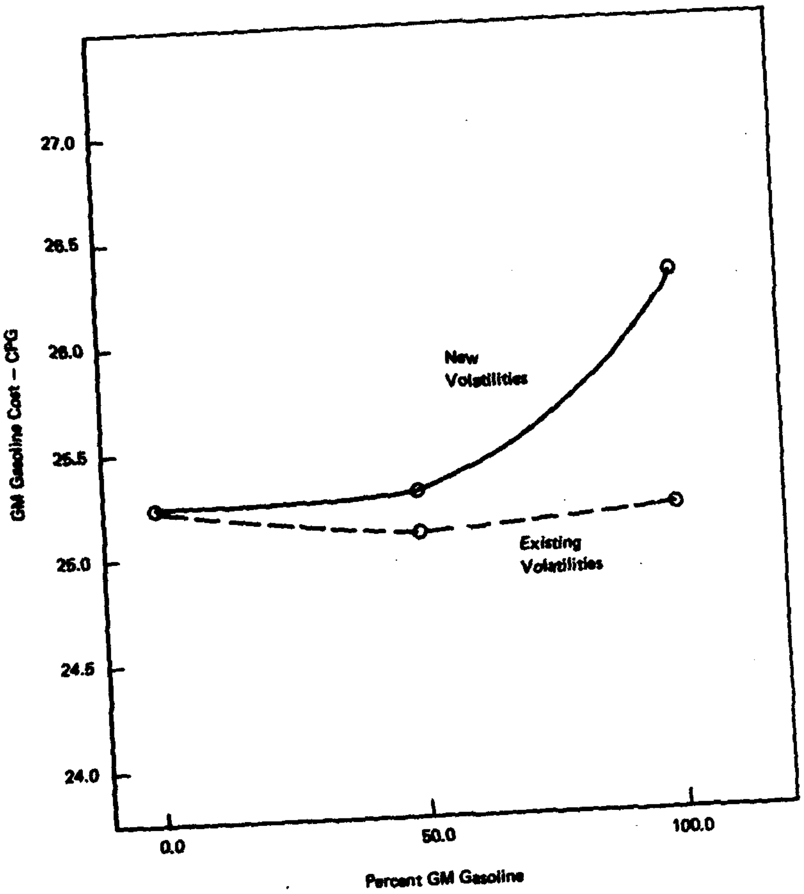


FIGURE 12 1980 OPERATIONS – GM GASOLINE COST VERSUS PERCENT GM GASOLINE
(Existing and New Volatilities – RON–91/MON–83)

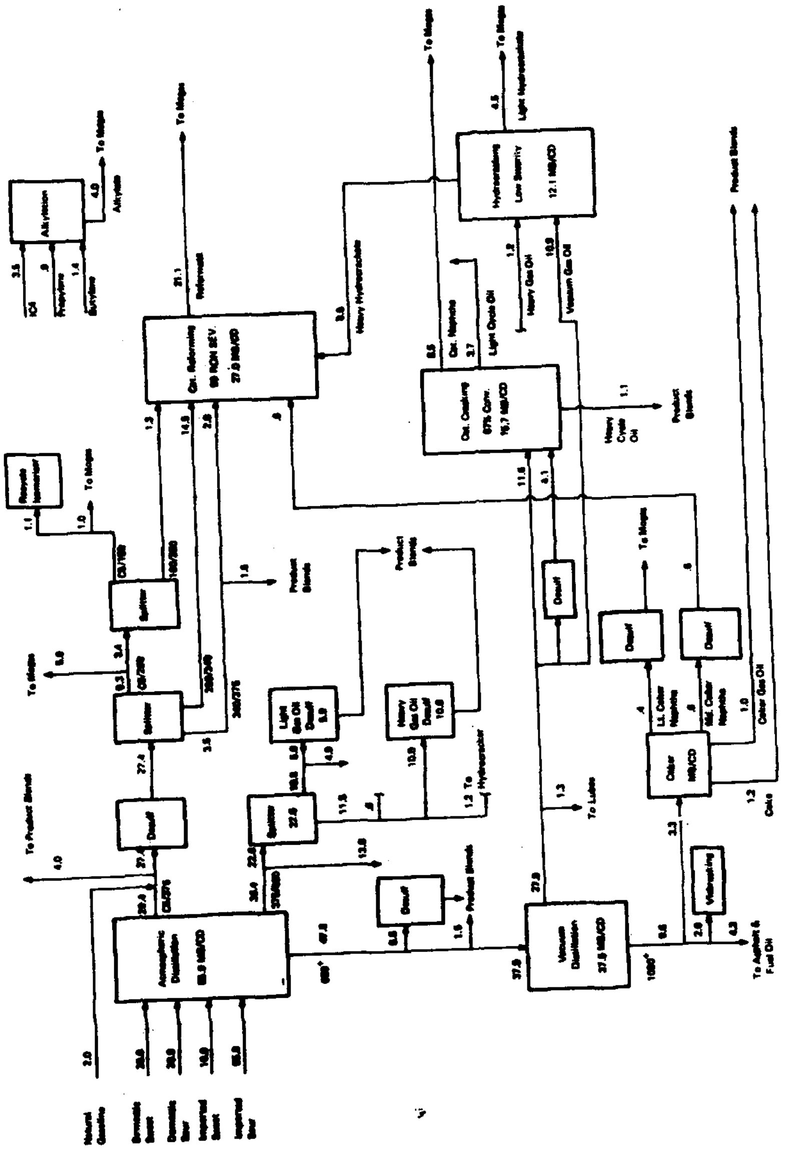


FIGURE 13 1980 – 100% GM 91/83 RON/MON
EXISTING VOLATILITIES

99 RON. Catalytic cracker intake decreased from 19.8 to 15.7 MB/CD with an offsetting increase in hydrocracking feed from 7.7 to 12.1 MB/CD. Polymerization operations were discontinued and all olefins were alkylated. All these operating changes are consistent with the need to increase clear motor octane number which is required with the removal of lead. The other major processing change was the introduction of C5/C6 isomerization, another process which becomes attractive at reduced lead levels due to the high lead susceptibility of light straight-run blend stocks.

The next set of parametric runs was made with 50% of the refinery gasoline pool being supplied as GM grade gasoline at both the new and existing volatilities. The percent reduction of total gasoline make is shown in Figure 14 for increasing motor octane numbers of the lead-free grade. Up to 87 clear motor octane number can be made at the new GM volatilities and up to 89 clear motor octane number at existing volatilities before any yield decline occurs. Figure 15 shows the same results with the gasoline reduction reflected as percentage of the GM grade rather than the total pool, which doubles the magnitude of the decline.

Figure 16 shows the increased GM gasoline manufacturing costs with increasing motor octane number at 50% GM gasoline production. An increase of 8 motor octanes (from 83 to 91) results in an increase of nearly 7 CPG in manufacturing costs with existing volatility specifications.

Figure 17 is similar to Figure 16 and shows the increased GM gasoline manufacturing costs for new volatilities under the 1980 Scenario II base case. The 50% of the total gasoline pool treated as conventional grade structure contained only 3% premium and 41% 92/84 lead-free. The results of this series of runs essentially duplicated those starting from the Scenario I base case.

The next set of parametric runs was at 100% GM gasoline production at increasing motor octane number. In this series of runs the change from feasible to infeasible operation as a function of motor octane number was so rapid that the gasoline yield declined from 100% to 0% within an increase of only one whole motor octane unit. Thus, all the points shown in Figure 18 (which plots increased manufacturing costs versus motor octane number), maintained 100% yield of the base case. Again the rapid increase in manufacturing costs associated with higher motor octane numbers is readily apparent.

To test the sensitivity of our results to even greater increases in purchased crude prices, we made a set of runs at $10/Bbl delivered cost for imported sour crude oil. The new 1980 base case (under Scenario I) calculated an increase in composite gasoline cost from 25.26 CPG to 35.50. Figure 19 shows the increased gasoline costs versus motor octane number and displays a similar (though slightly steeper) slope than that shown in Figure 18.

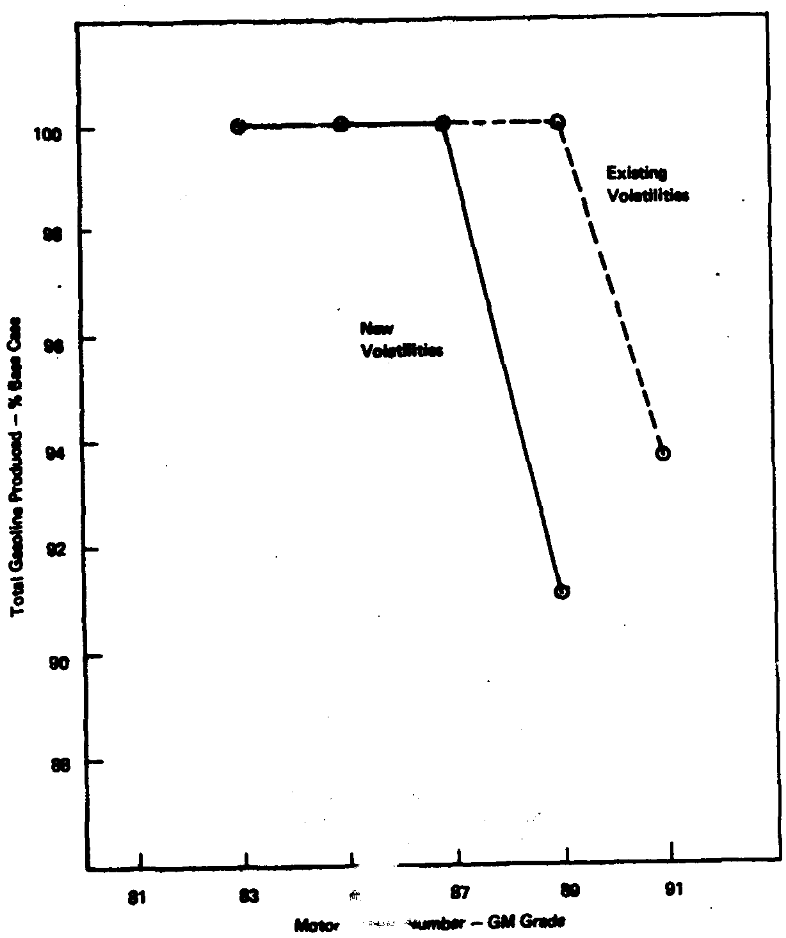


FIGURE 14 1980 OPERATIONS – TOTAL GASOLINE PRODUCTION VERSUS MOTOR OCTANE NUMBER – GM GRADE (Existing and New Volatilities – 50% GM)

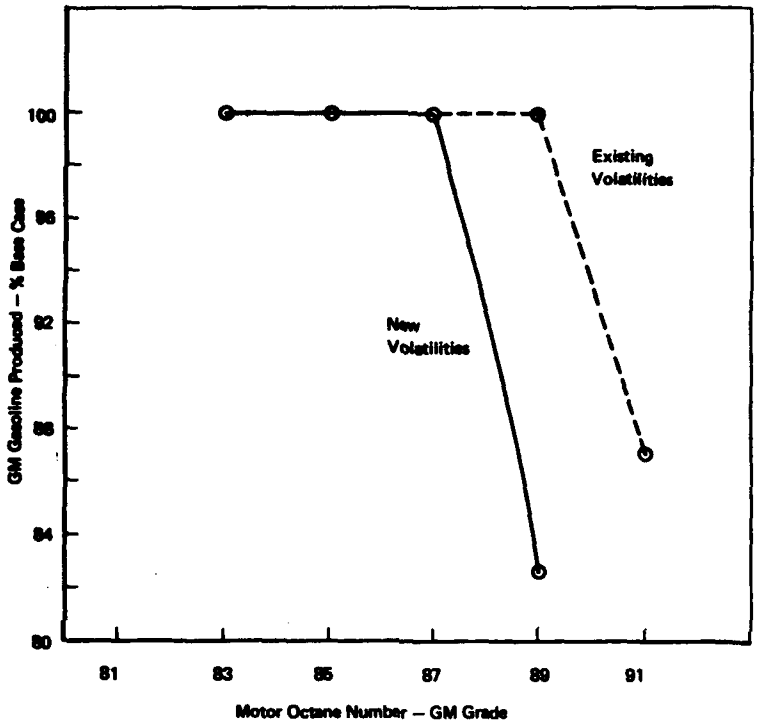


FIGURE 15 1980 OPERATIONS – GM GASOLINE PRODUCTION VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing and New Volatilities – 50% GM)

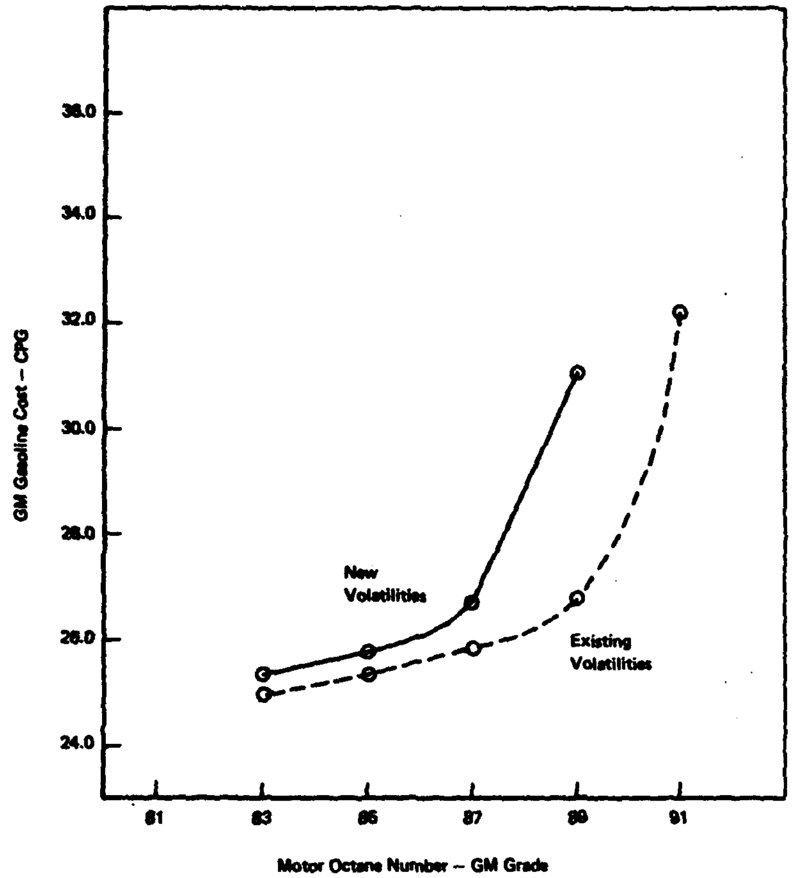


FIGURE 16 1980 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing and New Volatilities – GM Gasoline: 50%)

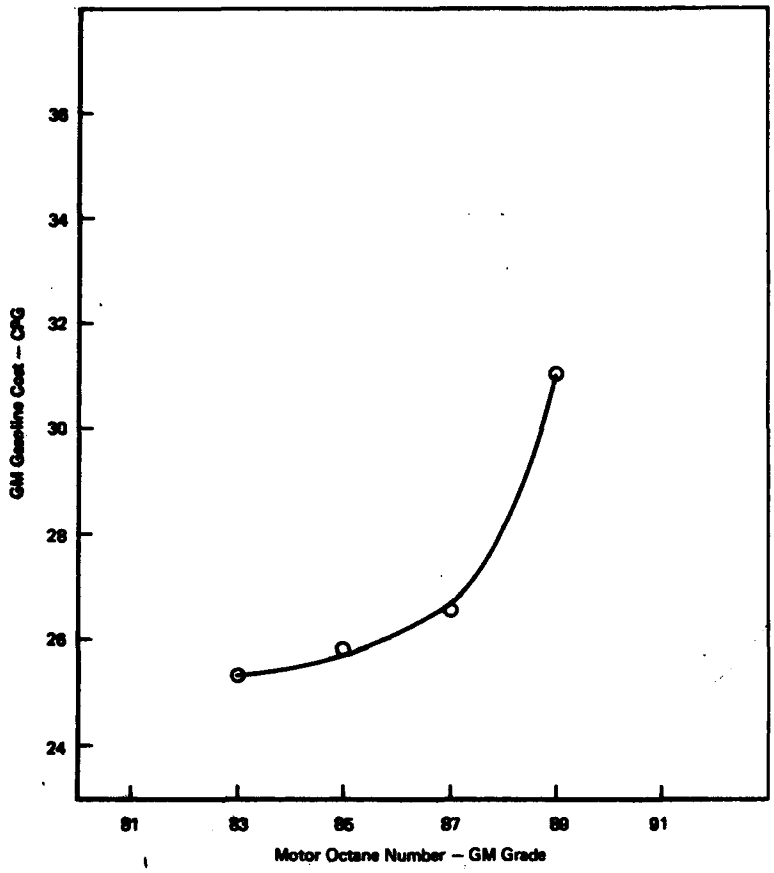


FIGURE 17 1980 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE
(New Volatilities – GM Gasoline: 50%)
(Low % Premium in Conventional Grades)

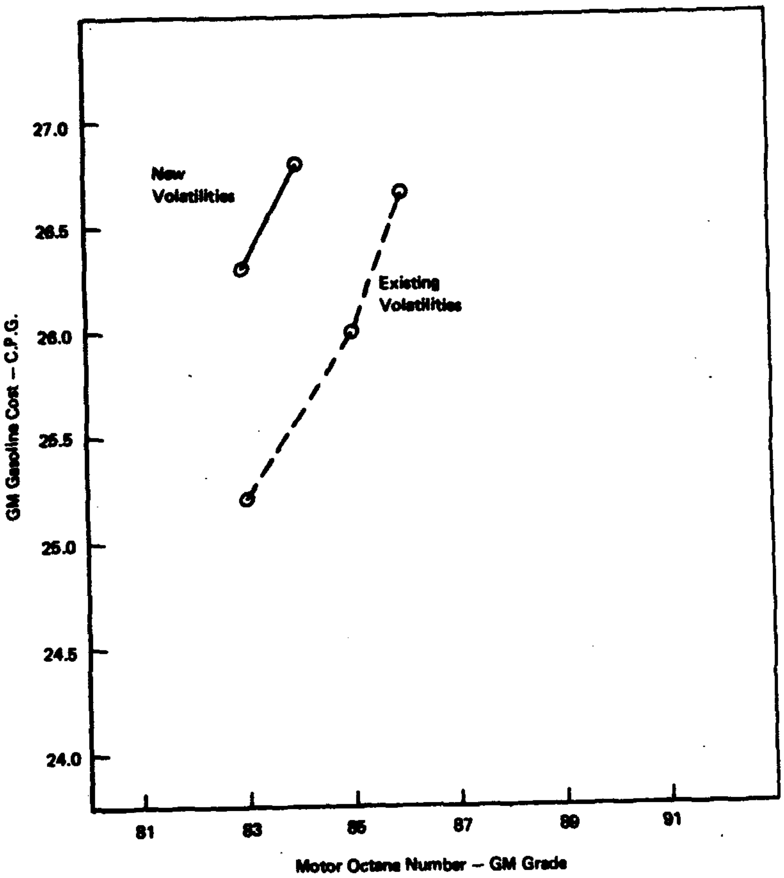


FIGURE 18 1980 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE (Existing and New Volatilities – GM Gasoline: 100%)

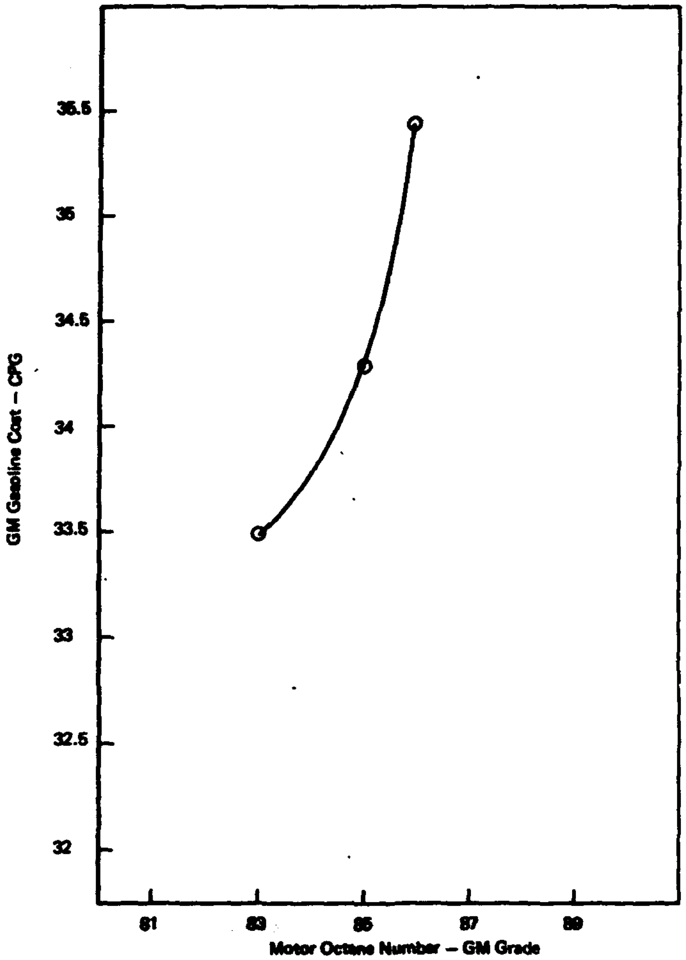


FIGURE 19 1980 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing Volatilities – GM Gasoline: 100%)
(Imported Sour Crude Price – $10/Bbl)

3. Capital Investments

The output from the optimized 1980 runs provided the refining capital investments required to achieve the increased product demands as well as associated product manufacturing specifications. These results are presented in Table XI. The base case for Scenario I (that is, continuing present motor gasoline grade structure) would require a refinery capital investment of $15 billion to achieve the increased product demand requirements by 1980. The alternative capital requirements shown in Table XI represent investments which would be required to achieve different volume levels and product specifications for unleaded gasoline production. The most severe case (i.e., making 100% GM gasoline at 94/86 RON/MON and existing volatilities) would require $19.3 billion rather than the $15 billion for the base case, or a net increase of $4.3 billion of capital investment. Thus, it appears that the huge refining capital investments that will be required by 1980 to expand supply of total products are not particularly sensitive to the percentage requirements for lead-free gasolines as long as the octane levels are moderate.

Although the capital requirements to produce 100% GM at 91/83 with new volatilities are less than with existing (16.2 versus 17.2), it must be remembered that the model optimizes the composite of raw material, operating and capital costs. Figure 12 illustrates that the resultant gasoline cost is more than 1 CPG higher for the new volatilities.

The 1980 base case for Scenario II (i.e., a significant change in engine design by 1975 such that essentially no premium gasoline and a large percentage of lead-free, low octane gasoline is required for 1980) results in essentially the same refinery capital expenditure for 1980 as the alternative scenario. The reduced manufacturing cost for this case (25.0 CPG versus 25.26) is due to reduced raw material requirements and operating expenses rather than a reduction in refining capital.

TABLE XI

NEW REFINING INVESTMENT REQUIRED
1973→1980 PERIOD
$ BILLION

BASE CASE (EXISTING GASOLINE SPECS) = $15.0 BILLION

GM Octane	Existing Volatilities		New Volatilities	
RON/MON	50% GM	100% GM	50% GM	100% GM
91/83	15.2	17.2	15.8	16.2
92/84	–	–		16.9
93/85	15.9	19.0	16.5	
94/86	–	19.3	–	
95/87	16.9		17.3	
97/89	18.2			

APPENDIX

ARTHUR D. LITTLE REFINERY SIMULATION MODEL

A. MODEL DESCRIPTION

Over the past several years, Arthur D. Little has developed large-scale computer models for simulating the major world refining centers. In such models a specified product demand pattern is met by a specified crude slate in an optimized refinery operation. An analysis of model outputs offers valuable insight into crude and refined product values with respect to the stated cost of a reference crude oil. In effect, the model continuously answers the questions: "What will it cost to produce an additional barrel of Product X?" and "What would an additional barrel of crude oil Y be worth relative to the reference crude oil and the other crude oils in the crude oil slate?"

A simplified refinery flow sheet shown in Figure 1 represents one of the models. This particular one is of the U.S. East Coast, but other models are similar. Each crude is allowed to select its own optimum processing scheme by the model simulating "blocked-out" operation. For example, the processing scheme chosen for Brega is most likely quite different from that selected for Tia Juana. The intermediate streams from each process unit can either be further processed or allocated to final product blending.

The main blocks of the refinery processing scheme can be broken down into: (a) naphtha, (b) gas oil, and (c) residual. The full-range (C5 – 400° F) untreated naphtha can be sold directly. Otherwise, the naphtha is split into several fractions for blending or further processing. The light (175-250) and heavy (250-400) naphthas can each be hydrotreated. Each hydrotreated naphtha can be routed to a catalytic reformer with the option of running at three different octane severities. The model chooses the optimum severity or it can bypass some naphtha into finished product blending.

The gas oil processing scheme is less complex than the naphtha. The full-range 400-650° F fraction can be split into a kerosene fraction and heavy gas-oil fraction, and each stream can be subsequently hydrotreated.

The residual fraction (atmospheric bottoms) can be directly blended to residual fuel oil or desulfurized before blending if from a sour crude origin. It can also be fed to a vacuum distillation unit; the vacuum overhead stream can then be hydrotreated for fuel-oil blending or fed to a catalytic cracker for conversion into lighter products. The model is allowed the option of choosing between two catalytic cracking conversion levels or two grades of vacuum gas oil feed. The propylene-butylenes from catalytic cracking can be fed to an alkylation unit or to a polymerization unit to make gasoline blending stocks. Vacuum bottoms can be

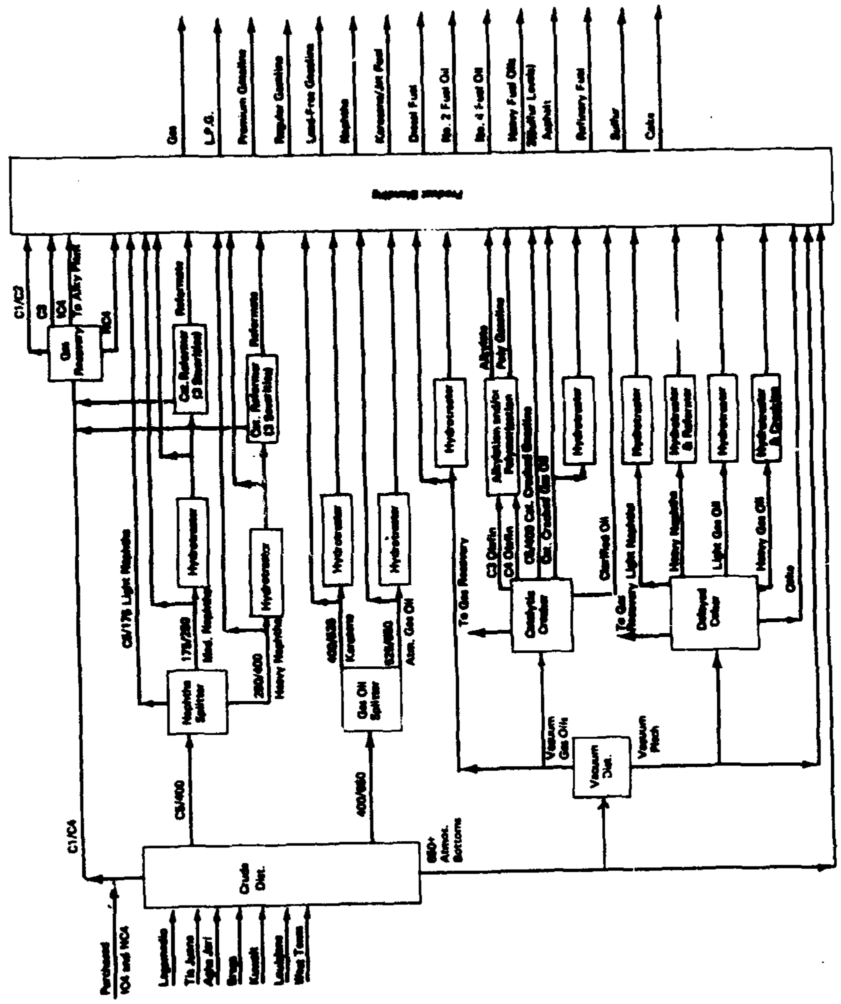


FIGURE 1 REFINERY FLOW SHEET
U.S. EAST COAST MODEL

routed to a coker to reduce the production of fuel oil and to produce some lighter products and coke. The coker naphtha can be hydrotreated and the heavy fraction reformed. The coker gas oil can also be hydrotreated and the heavy fraction cracked.

Additional processes in the model not shown on this refinery flow sheet include a hydrogen plant. (If the volume of hydrogen required for treating exceeds that supplied from catalytic reforming, then hydrogen must be manufactured either from refinery gas, naphtha and/or residual fractions). The refinery is usually required to generate its own steam and power, although these can be variable options. A sulfur plant is provided which converts hydrogen sulfide into elemental sulfur.

ADL has accumulated industry data for each processing unit for each crude oil. This includes yields and key properties of the products from that particular process, capital costs, and operating costs divided into the following seven categories: refinery fuel consumption, steam, water, electric power, catalysts and chemicals, operating labor, and maintenance. The capital and operating costs for each refinery process unit are based on modern units of the size consistent with 100 MB/D crude distillation capacity.

The costs of offsites for crude handling and product blending and storage is included and varies with crude distillation capacity. An internal refinery fuel balance is maintained (including fuel needed for steam generation, power generation, etc.) with a maximum sulfur content specification.

B. ECONOMIC BASIS

The data supplied to the model for the computer runs consist of:

1. Product demands and specifications;

2. Crude supply; and

3. Refinery processing options for each crude.

Product demands are usually fixed volumes which must be met. However, we occasionally allow a particular product volume to optimize at a specified netback, sometimes limiting minimum or maximum levels.

The basic assumption underlying our use of fixed product demands is that the total market for petroleum products in a refining center is relatively inelastic to changes in product prices. This is most true for products such as gasoline and jet fuel which have no competitive supply source. Heating oil and residual fuel have had inter-fuel competition from natural gas and coal in the past. One result

of this is that residual fuel has been sold below its investment cost value. If we expect this condition to continue, we can remove the fixed volume restriction from residual fuel oil and allow it to seek its own optimum production level at an inter-fuel competitive price structure.

In a multi crude system, crude slate is usually specified as a fixed supply for all crudes except a reference crude which must be allowed to vary in order to meet a fixed product slate because it is not known in advance the exact volume of crude oil that will be required due to gains/losses from refinery processes and own fuel consumption. The volume of the reference crude consumed will vary somewhat from run to run. A delivered price is assigned to this reference crude, and all other crude and product values are determined relative to the reference crude oil price chosen.

For each refinery process in the model, the capital cost is supplied plus several categories of operating costs. The capital cost is converted to a daily cost basis via a capital recovery factor which is usually 20% per year. The capital charge provides for depreciation, income tax, property tax and insurance, and profit.

The linear programming code will optimize the refinery processing scheme at minimum cost to meet the required product demands and product specifications from the crude slate provided. It is assumed that complete interchange of intermediate streams from all crudes is possible. Also, for product specifications that are binding, the products are always blended exactly on specification and no quality is given away. Of course, in the real world, there are inefficiencies in processing and blending. Thus, the conversion and treating unit intakes determined by the model, represent bare minimums and in the actual refineries some excess capacity will be required.

The most useful outputs from the linear programming runs are the optimum refined process schemes chosen for each crude oil and the shadow prices for the refined products and crude oils. These shadow prices indicate the internal refinery values for each respective product and each crude oil and indicate the minimum long-term selling price that a particular product requires in order to justify capital expenditures for its manufacture or the maximum long-term purchase price for each crude oil. The product values (sometimes called investment cost values) are often used by major oil companies as transfer values when transferring products from refining to marketing divisions and also from refinery to petrochemical divisions.

The relative crude values simulate the internal crude oil values assigned by large, integrated oil companies which have the flexibility to reallocate crudes among various refineries to optimize its operations in a large geographic region.

In parametric evaluations, we systematically vary certain key uncertainties in our input data (such as product demand levels, specifications, operating costs, crude supply patterns, etc.) to test the flexibility of model outputs to these changes. A parametric evaluation consists of an alternate unique LP solution for each variation in input data. We can thus evaluate on a quantitative basis the extent to which a variation in a particular input forecast will affect the conclusions, in particular relative product prices and crude values.

It is important to emphasize that the crude and product values generated by the refinery simulation model are costs and not prices. Market constraints can and do limit the extent to which a refiner can recover the costs allocated to each product in the model. However, the model does show when additional costs are incurred in making mo : of a particular product. It indicates a lower market value for high-sulfur crude oils and a higher market value for low-sulfur crude oils as the demand for low-sulfur products increases. The crude oil values are not prices but replacement values; that is, the value at which a refiner would replace a barrel of the reference crude with the barrel of another crude oil. A high replacement value for a given crude oil means that the refiner can reduce refining costs by substituting this crude oil for a low replacement value crude oil.

DETAILED REFINING DATA

A. PROCESS DESCRIPTION

The model is intended to represent the total or individual regions of the U.S. refining industry on the basis of a typical 100 MB/CD refinery. The refinery was set up to run four crudes – a sweet and sour domestic crude and a sweet and sour foreign crude. The crudes are South Louisiana Mix (36.2 API), West Texas Sour (33.4 API), Nigerian Mix (29.5 API), and Saudi Arabian Light (34.5 API). Any combination of these crudes can be considered marginal or with fixed volumes.

Investment and operating cost data for each of the refinery processes in the model are intended to represent the costs of units whose size is consistent with a 100 MB/CD refinery. Both capital and investment costs can easily be escalated to represent inflation for future situations. A process-by-process description is given below, highlighting the major assumptions used in producing their representation.

B. ATMOSPHERIC DISTILLATION

Each crude is represented by a separate vector in order that the differences in the various stream qualities may be represented in downstream processes. Investments and maintenance costs for sour crudes are higher than for sweet crudes to reflect disadvantages of increased sulfur in the feedstock. In addition, the percentage of sour crudes run can be controlled by having a capacity restriction on these crudes.

C. VACUUM DISTILLATION

Once again, each crude has its own vacuum distillation vector to enable downstream processing to reflect the differences in stream yields and qualities.

D. CATALYTIC REFORMING

Naphtha from each crude has its own reforming vectors. Each crude specific naphtha is broken down into three feeds available for reforming – light, medium, and heavy. The light (160-200° F) and medium (200-340° F) feeds produce reformates which will meet the end point specifications of 365° F maximum on the special gasoline being studied for General Motors. The heavy feed, a 340° F to 375° F feed produces a reformate which does not meet the General Motors mogas E.P. spec. but is acceptable in conventional gasolines.

For light and medium feeds, four reforming severities are represented giving 90, 95, 100 and 103 Research Octane clear product. For heavy feed only 90, 95 and 100 severity are included since it is unlikely that this feed will be reformed at the highest severity for lead-free, low end point gasoline.

Feed capacity restrictions (of 1.03 and 1.06) are incorporated on operations at 100 and 103 severity to reflect the fact that existing reformers are designed for severities in the 90 to 95 clear octane range. When considering future processing requirements these restrictions are, of course, released.

Reforming of hydrocrackates from low severity operation is also represented at 90, 95, 100 and 103 severity. Reformate from these operations does not meet the 365° F end point specification because the feed hydrocrackate has too high an end point. In order to reduce the end point of the hydrocrackate, a special set of high severity hydrocracking operations is represented in the model and these are discussed later. The reformate from the reforming of this low end point hydrocrackate feed will then meet the 365° F end point specification.

Investment and operating costs for different reformer severity operations are increased with increasing severity to reflect the fact that higher investment would be required for a higher severity reformer and it would be more costly to operate.

E. CATALYTIC CRACKING

Catalytic cracking is represented by six options, namely a low and high severity operation on a sweet feed, a sour feed and a desulfurized sour feed. Only vacuum gas oil in the boiling range of 650° F to 1,050° F is considered as a feed since this is fairly typical of U.S. catalytic cracking operations. Lighter distillates can be hydrocracked.

Low severity operation is set at 65 volume percent conversion and high severity is set at 85%. Yields are based on Zeolitic type catalysts and are given in Table 1. A higher capacity utilization of 1.05 is placed on the high severity operation since most catalytic crackers are not designed to handle the same amount of fresh feed at high severity, even with a Zeolitic type catalyst.

Investments and operating costs are higher for the high severity operation and for the sour feed cases.

F. CATALYTIC CRACKED NAPHTHA SPLITTING

The catalytic cracked naphthas produced have end points around 430° F and, as such, are not suitable to meet a 365° F end point gasoline. In today's refining operations catalytic naphthas are normally split into a light and heavy naphtha. The light naphtha would, of course, meet the 365° F end point, but the heavy would not. Therefore, in addition to this normal splitting operation, we have added an alternative which produces a light catalytic naphtha, a medium catalytic naphtha, and a very light cycle oil. The medium catalytic naphtha will meet a 365° F end point and the light cycle oil produced can go to distillate blending.

TABLE 1

CAT CRACKING YIELDS USED IN U.S. REFINING MODEL

Feed	Sweet Vacuum Gas Oil Feed		Sour Vacuum Gas Oil Feed		Hydrotreated Sour Vacuum Gas Oil Feed	
Products LV%	Low Conversion	High Conversion	Low Conversion	High Conversion	Low Conversion	High Conversion
Fuel Gas (FOE)	0.025	0.048	0.025	0.048	0.018	0.033
C3 Olefins	0.052	0.070	0.052	0.070	0.066	0.075
Propane	0.013	0.030	0.013	0.030	0.020	0.043
C4 Olefins	0.076	0.108	0.076	0.108	0.061	0.116
Isobutane	0.046	0.090	0.046	0.090	0.070	0.128
Normal Butane	0.008	0.022	0.008	0.022	0.012	0.031
C5-430 Mogas	0.520	0.600	0.520	0.600	0.580	0.669
Light Cycle Oil	0.270	0.100	0.270	0.100	0.212	0.033
Heavy Cycle Oil	0.080	0.050	0.080	0.050	0.063	0.017
Total	1.090	1.118	1.090	1.118	1.112	1.145
H_2S (Lbs/Bbl)	0.382	0.382	2.995	2.995	0.382	0.382

G. HYDROCRACKING

Hydrocracking operations are represented by twelve vectors. Half of these represent existing operations and what we have termed low severity hydrocracking. The other half are the special high severity operations which produce low end point hydrocrackates to make reformate suitable for blending in 365° F end point gasoline. More hydrogen is consumed and feed capacity is reduced 5% for this operating mode.

Six types of feeds are allowed to the hydrocrackers, namely a sweet and sour feed of each of atmospheric heavy gas oil, vacuum gas oil, and cracked gas oil. All cracked gas oils are considered to have the same yields and these feeds include catalytic cycle oil, coker gas oil, and visbreaker gas oil. Table 2 lists both the low and high severity yields used in the study. Both investments and operating costs for sour operations and high severity operations are higher than for sweet low severity operations.

H. ISOMERIZATION

Isomerization of light naphthas (C5/160) has been included as an additional processing option which is likely to be required for the production of lead-free gasoline. Both once-through and recycle isomerization of each of the four crude specific light naphthas are included in the model.

I. OTHER GASOLINE PROCESSES

The other gasoline processes represented in the model are Polymerization and Alkylation.

J. OTHER CONVERSION PROCESSES

Other conversion processes represented are Coking and Visbreaking, which differentiate between sweet and sour feedstocks.

K. DESULFURIZATION

Desulfurization of naphthas, light and heavy gas oils, and vacuum gas oils from all crudes are included as processing options in the model. In addition, direct desulfurization of sour atmospheric bottoms (650° F+) to sulfur levels of 1.0 wt% and 0.5 wt% are included.

Cycle oils from sour catalytic cracking operations also have the option to be desulfurized. Naphthas from coking operations are required to be desulfurized before routing to product blending or reforming.

TABLE 2

HYDROCRACKING YIELDS USED IN U.S. REFINING MODEL

Product Streams	Low Severity						High Severity					
	Heavy Atmos. Gas Oil Feed		Vacuum Gas Oil Feed		Cracked Stock Feed		Heavy Atmos. Gas Oil Feed		Vacuum Gas Oil Feed		Cracked Stock Feed	
	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour
H_2S (Lbs/Bbl)	.285	3.62	1.033	8.09	1.896	10.00	.285	3.62	1.033	8.09	1.896	10.00
H_2 (MSCF/Bbl Required)	1.900	*1.950*	*2.050*	*2.100*	*3.100*	*3.150*	2.090	2.145	2.255	2.310	3.410	3.465
C_2	.0040	.0040	.0067	.0067	.0050	.0050	.0078	.0078	.0111	.0111	.0106	.0106
C_3	.0540	.0540	.0768	.0768	.0670	.0670	.0800	.0800	.1123	.1123	.1056	.1056
IC_4	.1440	.1440	.1520	.1520	.1170	.1170	.1994	.1994	.2079	.2079	.1722	.1722
nC_4	.0600	.0600	.0630	.0630	.0520	.0520	.0796	.0796	.0826	.0826	.0733	.0733
Light Hydrocrackate	.3640	.3640	.3820	.3820	.3170	.3170	.4577	.4577	.4747	.4747	.4238	.4238
Heavy Hydrocrackate	.6600	.6600	.6920	.6920	.7800	.7800	.5129	.5129	.5378	.5378	.6062	.6062
Vol. % Yield	1.286	1.286	1.3715	1.3715	1.338	1.338	1.3374	1.3374	1.4264	1.4264	1.39	.3915

Investment and operating costs on the sulfur manufacturing process include provision for a centralized H_2S gas scrubbing system which is necessary when producing elemental sulfur and is not included as part of each individual hydrotreating process.

L. GASOLINE BLENDING

The gasoline blending data was developed from other published studies such as *U.S. Motor Gasoline Economics – A.P.I. June 1, 1967* supplemented by our own in-house analysis and is presented in Table 3.

TABLE 2

MOGAS COMPONENT BLENDING QUALITIES
REFORMATES

Component	R.V.P.	RON Clear	RON 0.5CC	RON 3.0CC	MON Clear	MON 0.5CC	MON 3.0CC	Volatility % Distilled At °F 130	160	190	210	280	310	330
Reformate 90														
Lt. feed	10.8	90.5	93.7	97.8	80.1	84.8	90.0	4.0	12.2	71.5	93.1	100.0	100.0	100.0
Med. feed	5.3	90.5	93.7	97.8	80.1	84.8	90.0	0.5	2.8	10.3	17.4	83.7	92.5	97.9
Heavy feed	1.4	90.5	93.7	97.8	80.1	84.8	90.0	-1.0	-0.5	0.0	0.8	14.9	22.3	34.9
Reformate 95														
Lt. feed	11.0	95.3	97.2	100.2	82.1	87.4	91.6	4.8	13.5	77.0	94.5	100.0	100.0	100.0
Med. feed	5.5	95.3	97.2	100.2	82.1	87.4	91.6	1.6	3.6	11.3	18.5	84.7	93.2	98.0
Heavy feed	1.5	95.3	97.2	100.2	82.1	87.4	91.6	-1.0	-0.5	0.0	1.0	14.5	22.5	34.0
Reformate 100														
Lt. feed	11.3	99.8	101.8	102.9	86.0	90.5	93.5	8.5	17.0	83.0	96.2	100.2	100.2	100.2
Med. feed	5.8	99.8	101.8	102.9	86.0	90.5	93.5	4.4	6.5	13.6	20.2	85.7	93.6	98.2
Heavy feed	1.8	99.8	101.8	102.9	86.0	90.5	93.5	1.0	2.4	2.5	2.7	16.5	23.0	34.2
Reformate 103														
Lt. feed	11.6	102.5	104.1	104.7	88.0	92.9	96.0	11.2	19.7	88.5	97.9	100.3	100.3	100.3
Med. feed	6.1	102.5	104.1	104.7	88.0	92.9	96.0	6.5	8.7	15.3	21.8	86.5	94.4	100.1
Heavy feed	2.1	102.5	104.1	104.7	88.0	92.9	96.0	2.5	4.8	4.5	4.5	17.0	24.0	34.3
Lt. refm. Ex 95 Md feed	11.5	84.4	86.7	92.3	71.9	79.0	86.8	8.5	20.0	66.5	87.0	100.0	100.0	100.0
Hy. refm. Ex 95 Md feed	1.5	102.6	104.2	105.5	88.9	93.0	95.6	-6.0	-2.8	0.0	0.0	32.0	66.5	91.0
Lt. refm. Ex 100 Md feed	11.9	90.5	93.0	95.1	77.0	83.3	89.0	10.0	23.0	68.0	89.0	100.0	100.0	100.0
Hy. refm. Ex 100 Md feed	1.7	108.0	107.7	108.1	92.0	96.3	96.5	-4.0	-1.5	0.0	9.0	34.0	67.0	93.0
Reformate 90														
Heavy hydr. feed	6.4	90.5	93.7	97.8	80.1	84.8	90.0	1.2	4.2	14.0	22.0	60.9	78.2	88.8
Mod. heavy hydr. feed	7.4	90.5	93.7	97.8	80.1	84.8	90.0	1.5	4.8	15.2	25.3	83.8	92.4	97.6
Reformate 95														
Heavy hydr. feed	6.7	95.3	97.2	100.2	82.1	87.4	91.6	3.3	6.6	16.3	24.5	61.2	70.5	88.0
Mod. heavy hydr. feed	7.7	95.3	97.2	100.2	82.1	87.4	91.6	3.7	7.3	18.1	30.0	84.2	92.7	97.5
Reformate 100														
Heavy hydr. feed	7.0	99.8	101.8	102.9	86.0	90.5	93.5	6.4	9.7	18.8	26.2	62.0	71.0	88.1
Mod. heavy hydr. feed	8.0	99.8	101.8	102.9	86.0	90.5	93.5	7.1	10.8	20.9	31.5	85.2	93.1	97.7
Reformate 103														
Heavy hydr. feed	7.3	102.5	104.1	104.7	88.0	92.9	96.0	8.6	11.5	21.2	27.9	62.5	71.0	89.3
Mod. heavy hydr. feed	8.3	102.5	104.1	104.7	88.0	92.9	96.0	10.0	14.0	23.0	33.0	86.0	93.5	97.9
Reformate 95														
Coker Naphtha feed	4.5	95.3	97.2	100.2	82.1	87.4	91.6	1.6	3.6	11.3	18.5	84.5	80.0	94.0
Reformate 100														
Coker Naphtha feed	4.8	99.8	101.8	102.9	86.0	90.5	93.5	4.4	6.5	13.6	20.2	85.5	80.4	94.2

TABLE 3 (Continued)

STRAIGHT RUN GASOLINES AND ISOMERIZED GASOLINES

Crude – Component	R.V.P.	RON Clear	RON 0.5CC	RON 3.0CC	MON Clear	MON 0.5CC	MON 3.0CC	Volatility % Distilled At °F 130	160	180	210	230	250	280	SG
Arabian Light															
C_5/375 (27.3 LV%)	3.6	39.8	46.7	65.0	39.6	46.0	63.6	0.0	3.0	16.0	28.5	72.5	81.5	90.0	.738
C_5/160 (4.9 LV%)	11.0	66.0	72.3	85.6	64.5	69.6	82.2	68.2	91.3	105.0	100.0	100.0	100.0	100.0	.657
160/200 (3.3 LV%)	6.0	52.3	57.4	73.7	51.8	56.5	73.5	0.0	0.9	80.0	105.0	100.0	100.0	100.0	.687
C_5/200 (8.2 LV%)	9.0	60.5	66.3	80.8	59.4	64.3	78.7	30.0	53.5	96.0	105.0	100.0	100.0	100.0	.669
Louisiana Mix															
C_5/375 (23.6 LV%)	3.2	56.6	62.4	77.3	58.1	62.7	75.9	0.0	0.5	11.0	19.5	66.5	77.0	87.5	.761
C_5/160 (3.7 LV%)	11.0	73.5	80.2	91.1	77.0	80.7	88.7	68.2	91.3	105.0	100.0	100.0	100.0	100.0	.668
160/200 (2.7 LV%)	4.1	72.8	77.1	88.5	74.4	77.4	87.3	0.0	0.0	70.0	105.0	100.0	100.0	100.0	.727
C_5/200 (6.4 LV%)	8.1	73.2	78.9	90.0	75.9	79.3	88.1	20.0	41.0	87.0	95.0	100.0	100.0	100.0	.693
West Texas Sour															
C_5/375 (28.3 LV%)	3.7	58.8	62.2	72.9	56.3	59.2	68.7	0.0	1.1	13.5	26.5	72.5	82.5	91.5	.746
C_5/160 (5.7 LV%)	11.5	71.3	77.3	89.1	75.0	77.8	84.8	68.2	91.3	105.0	100.0	100.0	100.0	100.0	.664
160/200 (3.8 LV%)	5.0	70.1	74.3	85.6	72.3	74.1	82.6	0.0	0.0	75.0	105.0	100.0	100.0	100.0	.732
C_5/200 (9.5 LV%)	8.9	70.8	76.1	87.7	73.9	76.3	83.9	26.0	51.0	90.0	98.0	100.0	100.0	100.0	.691
Nigerian Forcados 29.5°															
C_5/375 (20.6 LV%)	3.2	66.5	70.7	81.3	64.0	67.7	78.1	0.0	0.5	9.0	17.5	63.0	74.0	88.0	.761
C_5/160 (2.7 LV%)	11.0	82.0	87.1	95.5	83.0	87.1	92.0	68.2	91.3	105.0	100.0	100.0	100.0	100.0	.670
160/200 (3.4 LV%)	4.1	78.8	83.9	93.1	79.8	83.9	90.6	0.0	0.0	70.0	105.0	100.0	100.0	100.0	.727
C_5/200 (6.1 LV%)	8.1	80.2	86.3	94.2	81.2	86.3	91.2	20.0	41.0	87.0	95.0	100.0	100.0	100.0	.702
Natural Gasoline															
C_5/160	12.0	79.5	84.6	94.1	78.3	81.9	90.0	68.2	91.3	105.0	100.0	100.0	100.0	100.0	.643
C_5/200	10.8	78.9	84.0	93.5	77.8	81.7	89.9	30.0	53.5	88.0	105.0	100.0	100.0	100.0	.672
Arabian Light															
Once Through Isomate	11.5	78.0	86.0	91.5	75.5	82.2	87.1	75.0	98.0	105.0	100.0	100.0	100.0	100.0	.650
Recycle Isomate	12.5	87.0	93.0	97.0	84.5	91.6	96.0	85.0	105.0	105.0	100.0	100.0	100.0	100.0	.640
Louisiana Mix															
Once Through Isomate	12.5	82.1	90.5	96.0	82.1	88.4	93.0	75.0	98.0	105.0	100.0	100.0	100.0	100.0	.650
Recycle Isomate	13.5	90.0	96.3	99.9	86.0	94.2	99.0	85.0	105.0	105.0	100.0	100.0	100.0	100.0	.640
West Texas Sour															
Once Through Isomate	12.5	81.0	89.5	96.0	81.0	86.7	91.0	75.0	98.0	105.0	100.0	100.0	100.0	100.0	.650
Recycle Isomate	13.5	89.0	95.1	98.9	85.5	93.2	98.0	85.0	105.0	105.0	100.0	100.0	100.0	100.0	.640
Nigerian Forcados															
Once Through Isomate	13.5	87.0	95.3	100.0	87.0	93.0	97.0	75.0	98.0	105.0	100.0	100.0	100.0	100.0	.650
Recycle Isomate	14.5	92.5	98.3	102.2	88.0	96.3	101.1	85.0	105.0	105.0	100.0	100.0	100.0	100.0	.640

TABLE 3 (Continued)

OTHERS

Components	RON				MON			Volatility % Distilled At °F						
	R.V.P.	Clear	0.5CC	3.0CC	Clear	0.5CC	3.0CC	130	160	190	210	280	310	330
Isobutane	71.0	100.5	104.4	109.0	95.8	101.3	106.3	115.0	115.0	110.0	110.0	100.0	100.0	100.0
N. Butane	65.0	95.0	97.9	103.2	89.9	98.2	101.0	115.0	115.0	110.0	110.0	100.0	100.0	100.0
C_3 Alkylate	6.8	91.5	96.5	101.9	87.0	93.5	101.1	5.6	15.0	37.0	53.2	97.5	98.8	100.0
C_4 Alkylate	3.5	96.5	99.7	106.9	91.8	96.2	105.1	0.2	1.5	9.3	29.3	97.7	99.0	100.0
Light Hydrocrackate	13.1	86.6	90.6	97.3	82.4	88.9	96.1	75.0	92.0	100.0	100.0	100.0	100.0	100.0
Poly Gasoline	1.0	100.2	99.5	101.5	83.2	86.3	86.5	-18.0	-13.0	-5.0	-2.0	13.5	42.0	78.0
Iso Pentane	20.4	93.1	97.5	102.7	87.5	94.5	101.9	110.0	110.0	100.0	100.0	100.0	100.0	100.0
68% Conversion Cat. Naphthas														
C_5-430 Cat. Naphtha	6.2	93.9	96.1	98.8	77.7	81.4	84.3	6.5	17.0	37.8	46.7	73.2	79.5	88.0
C_5-350 Cat. Naphtha	7.6	96.0	97.9	100.2	78.3	82.2	84.9	12.5	27.5	60.0	61.0	91.3	95.0	97.5
250-450 Cat. Naphtha	0.5	85.5	89.0	93.2	75.2	78.3	82.0	-35.0	-28.9	-15.0	-10.0	10.0	18.5	28.0
C_5-250 Cat. Naphtha	11.0	98.4	99.6	102.0	81.7	84.8	87.8	27.5	52.0	83.0	90.4	100.0	100.0	100.0
250-413 Cat. Naphtha	0.6	90.0	92.9	96.3	78.2	81.1	84.5	-25.0	-20.0	-10.0	-8.0	50.0	62.5	79.0
250-365 Cat. Naphtha	1.0	92.0	94.6	97.9	79.7	82.6	86.0	-20.0	-15.0	-5.0	-3.0	60.0	78.0	97.0
88% Conversion Cat. Naphthas														
C_5/430	6.2	98.3	98.1	100.2	80.1	83.4	85.7	6.5	17.0	37.8	46.7	73.2	79.5	88.0
C_5/350	7.6	98.4	99.9	101.6	80.7	84.2	86.3	12.5	27.5	60.0	61.0	91.3	95.0	97.5
250-450	0.5	87.9	90.9	94.6	77.7	80.2	83.3	-35.0	-28.0	-15.0	-10.0	10.0	16.5	26.0
C_5/250	11.0	100.9	101.6	103.4	84.1	86.8	89.2	27.5	62.0	63.0	90.4	100.0	100.0	100.0
250-413	0.6	90.5	93.4	96.8	78.7	81.6	85.0	-25.0	-20.0	-10.0	-8.0	50.0	62.5	79.0
250-365	1.0	92.5	95.1	96.2	80.2	83.1	86.5	-20.0	-15.0	-5.0	-3.0	60.0	78.0	97.0
Visbreaker Naphtha	3.3	62.3	66.0	71.4	56.6	59.1	62.6	0.0	3.0	11.0	18.0	78.5	87.0	98.0
Light Coker Naphtha	16.2	78.0	83.3	90.7	71.2	74.8	79.9	42.0	62.5	93.5	99.0	100.0	100.0	100.0
Medium Coker Naphtha	1.2	55.0	60.1	67.7	52.2	56.9	63.9	-15.0	-10.0	0.0	1.0	64.5	80.0	94.0

Mr. MILFORD. Am I also correct in understanding that the only reason why General Motors is not pursuing the development of a jet ignition dilute combustion engine is because of the 1976 statutory standards?

Mr. STARKMAN. Oh, but we are pursuing it. What we are saying is we cannot take the step of going into production.

Mr. MILFORD. I meant pursuing them into production.

Mr. STARKMAN. In addition to the reasons set forth in my statement we feel that until the matter of oxides of nitrogen control levels has been set that we would be ill-advised to go into production at any level. This is because we would have the same problems as to the kinds of control systems to apply to the stratified charge engine, if you want to call it that, as we have with the conventional engine.

Mr. MILFORD. I would like to agree with you in your statement that the program should be directed more toward fundamental research rather than hardware development. I'll buy that.

Mr. STARKMAN. Thank you.

Mr. BROWN. I think your statement on page 21 which seeks to define the area of useful Government R. & D. will be helpful to the committee.

As I have indicated earlier in exploring this problem, some of the criticism of this legislation comes from those who are fearful that this is an effort to intrude a Government agency into a private enterprise field, such as the production of automobiles.

Of course, that is not the intent of the legislation and it needs to be drafted in such a way as to market clear what the areas of responsibility appropriately are.

May I just pursue for a moment this testimony starting on page 9, which I referred to earlier, about electrified vehicles. By coincidence another subcommittee of this committee, The Energy Subcommittee, is studying alternate sources of electric power and other kinds of energy.

In fact, yesterday they were looking at developments in the field of photovoltaic conversion, the use of solar cells for the direct generation of electricity. I was immediately struck by your description of electric vehicles and your statement about the need for broad systems studies with the possibility of a system which would use the batteries of electric vehicles as a storage facility for photovoltaic electric generation which, of course, occurs during sunlight hours and does not necessarily meet the demand load, but which requires some storage.

The idea of having electric-powered vehicles which can be charged by photovoltaic solar energy conversion might solve two problems, in the power systems context. Has that ever occurred to your company?

Mr. STARKMAN. I might call upon Dr. Agnew to indicate the extent to which we are involved in photovoltaic cell development. I might ask the question, however, do you have in mind on board photovoltaic or a central accumulating station?

Mr. BROWN. Actually, what the committee has been looking at mostly—although not exclusively—are systems which would apply solar energy to home heating and cooling, basically flat plate collectors, perhaps combined with a photovoltaic component which would generate electricity to complement the heat generated by the flat plate collectors.

This is, of course, highly theoretical at this point, although the committee has gone quite far in solar energy areas. But there seems to

be some breakthroughs in the economics of photovoltaic conversion which might make it more attractive as a part of an individual home or apartment complex or manufacturing building to have solar generated electricity as well as solar generated hot water.

As I say, one of the problems with generating electricity in this fashion is that it requires storage. And the use of vehicle batteries for storage might be one of the feasible ways to do it. That is kind of far out, but if you would like to make a far out comment we would appreciate it.

Dr. AGNEW. I would only say that sometime ago in our research efforts we did look at photovoltaic cells on board a vehicle, as to their feasibility. After some work we concluded that the area requirements and the volume requirements did not make that a very promising approach, so we did not go further in that direction.

Now the battery-powered electric vehicle, of course, can receive its electric energy from any electrical source. And the type of thing you mentioned is certainly in order as one possibility. We have also taken a brief look at the possibility of solar cells as a product in our home environment division of the corporation.

We do not think the application of solar cells to home heating and water heating is more appropriate than to vehicles. We have looked at that briefly but have not moved seriously in that direction as yet.

Mr BROWN. The idea of having a relatively self contained energy supply system is becoming more attractive to a lot of people in this complex world. So far no one has ever considered the application of solar energy to transportation. It has been felt it had no applicability.

But if it could be used in connection with electric-powered vehicles, then it does have an applicability. It would obviate some of the problems created by the central power station, as you indicated in your testimony, such as the burning of coal and the other losses.

Gentlemen, I wish to thank you again for your testimony. I regret that the bells command us to appear on the floor or we would explore some other points of your testimony.

May I ask if you would be willing to supply answers to written questions from the committee at a future time?

Mr. STARKMAN. We would be delighted to.

[The information follows:]

GENERAL MOTORS CORP.,
Warren, Mich., August 7, 1974.

MR. FRANK R. HAMMILL, Jr.,
Counsel, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. HAMMILL: The following is in answer to your letter of June 17 posing several questions from Congressman Brown of California.

Question 1. Does the information on pages 103 to 109 of the February 4, 5 and 6 hearings of the Subcommittee match the information in your own files?

Answer. The data shown on Table 1 on page 103, insofar as it represents GM, is essentially correct. However, two changes should be made:

1. Under capital expenditures (1971) amount of $44.9 million should be $55.9 million,
2. Under total R&D expenditures (1968) amount of $763 million should be $736 million.

Table II on page 103 is correct with respect to GM expenditures. The data presented in Attachments I and II on pages 105–107 do not originate with or represent GM and therefore, we are unable to comment as to its accuracy. Data shown on Attachment III on pages 108 and 109 requires some minor corrections:

1. Under 1967, line 9 should read 19 instead of 16,

2. Under 1974, line 12 should read 135 instead of 155,

3. Under 1975, line 5 should read 346 instead of 345, and line 8 should read 3,531 instead of 3,581. Also, line 16 should read 1831 and line 18 should be 58 instead of 55,

4. Under 1976, line 15 should read 936 instead of 986.

Question 2. Do you have an estimate of the future expenditures of your company in the same categories that are listed in our February hearing record?

Answer. Data contained in Attachment III, pages 108 and 109, were developed early in 1973 as part of GM's request for suspension of the 1975 and 1976 emission standards. The categories shown were suggested by the guidelines published by the EPA in order to satisfy suspension procedures. Since that time we have accumulated actual data for 1973 to replace the projections which had to be used in the suspension requests. However, the actual data were developed for internal purposes only, since we were not asking for a suspension of any standard at the time they were prepared. Consequently, the data are not available in the specific categories contained in Attachment III.

A brief summary of actual 1973 expenditures for General Motors and current projections for 1974 and 1975 are shown in the following table:

GM EMISSION EXPENDITURES

[Dollar amounts in millions]

	Actual, 1973	Estimated 1974	Estimated 1975
Total emission expenditures	$309.5	$435.0	$200
Memo: Included above:			
Capital expenditures	123.6	264.3	40
Alternate powerplant development	53.0	[1] 65.0	[2]
Total emissions as a percent of total R. & D.	15.0	[2]	[2]
Total R. & D.	$1,238.0	[2]	[2]

[1] Total expenditures for development of alternate powerplants estimated to be over $65,000,000

[2] Not available.

Estimated 1976 R&D expenditures are not shown due to the uncertainty of the forward emission control program which prevailed until enactment on June 25, 1974 of the Energy Supply and Environmental Coordination Act of 1974.

Question 3. What mileage goals does your company have for each category of vehicle that you market, using the EPA mileage test cycle?

Answer. Our target for all GM models is to exceed 15 miles per gallon on the *GM City Suburban driving cycle* as soon as possible. We expect to achieve this on virtually all our 1977 models. The 15 miles per gallon on the GM City Suburban driving cycle is roughly equivalent to 12.5 miles per gallon on the EPA mission test cycle. 17% of our 1974 production presently meets this target.

In 1975 we expect a considerable improvement in fuel economy and with the planned changes and the new, smaller cars, we believe we will have the capacity to produce more than 40% of our 1975 production meeting the target fuel economy value. Most of this improvement for 1975 models will be due to the advanced emission control system built around the catalytic converter which we will use on all U.S. built 1975 model cars.

The emissions cleanup job is performed so well by the catalytic converter that we have been able to retune the 1975 engine to restore much of the fuel economy which has been lost in recent years. Other improvements in fuel economy will also result due to weight reductions in existing models, lower axle ratios and the use of GM's steel belted radial tires as standard equipment. There will also be increased usage of smaller displacement engines, improvement in automatic transmission efficiencies, and added changes will be made in our 1976 and 1977 models so that by 1977 GM fully expects to meet the target of 15 miles per gallon on virtually all its models when tested on the GM City Suburban driving schedule.

Question 4. Does your company have any vehicle weight goals? If so, what type of weight mix do you anticipate?

Answer. In all cars, but especially the larger models, a priority effort is being made to reduce weight. A relatively small weight savings can be quite important.

For instance, a 100-pound reduction in the weight of the body can result in a savings of another 100 pounds in the structure, suspension, brakes and other components. A 200-pound reduction in the total vehicle weight can permit the use of a lower axle ratio or a smaller displacement engine, further improving fuel economy with no loss in performance. Because of these relationships, the primary way we intend to meet the market demand for improved fuel economy with our larger models is through the reduction of weight. We expect fuel economy savings of seven to eight gallons each 10,000 miles for each 100 pounds of weight reduction.

As I am sure the Committee is aware, about half of the weight increase experienced by our models over the last six to eight years is due to equipment added to meet federally mandated safety, damageability and emission requirements. We have asked NHTSA to reexamine some of those safety and damageability requirements which have required the largest weight increases, to be certain that the tradeoff between weight and economy is justified. Future safety requirements either pending or enacted, will require further substantial weight increases. These too, we hope NHTSA will review.

Question 5. What restraints does your company face on phasing in the stratified charge engine?

Answer. There are many different engine configurations which can be termed as "stratified charge". By the stratified charge engine I assume you mean what we classify as the "torch" ignition engine presently exemplified by the Honda Corporation developments.

While we have been able to obtain low levels of HC and CO emissions from such engines, presently we do not have proven durability. More importantly, however, is our concern over the ability of this engine to meet future automotive oxides of nitrogen standards. If we are to meet those NO_x standards originally stipulated in the 1970 Clean Air Amendments (.4 gpm), then it would appear necessary that we add essentially the same equipment to the "torch" ignition engine that we must add to the present open chamber gasoline piston engines. If we must do this, then there is little incentive to abandon the present engine. Therefore, there are two major restraints we face in phasing in an alternate power plant:

1. The potential requirement of designing the engine so that it will meet the statutory oxides of nitrogen standard.
2. The lack of durability information supporting the use of the engine in the hands of the consumer.

GM, of course, continues to work toward the development of other emission control technology and alternate engines.

Question 6. What time frame for production does your company see for the various alternative technologies that your statement referenced?

Answer. As was indicated in the statement, most of these alternate engine concepts have not been fully developed for adaptation to automobile usage. Further, durability of most of these systems has not been proven. But again, most importantly, is the fact that in almost every one of these instances the engine is unable to meet the statutory NO_x standard in their present forms. Until there is satisfactory assurance that the restrictive .4 gpm NO_x level will *not* be required in the future, we cannot set about developing rational production plans for any of the alternate technologies discussed in my statement.

Question 7. Could you explain why the domestic automobile manufacturers in the United States all market basically the same engine types while foreign manufacturers manufacture varying engine types? In other words, why is there not a mix of propulsion systems and engines from the U.S. manufacturers?

Answer. I do not agree with the assumption made in the question that foreign manufacurers offer a much larger variation in engine types than do domestic manufacturers. I believe that with only three exceptions, the Mercedes Diesel, the Mazda rotary and the Honda "torch" ignition engine—the total production of which constitutes but a minimal fraction of total world sales—all vehicle manufacturers use the same spark ignited gasoline piston engine. That being the case, the degree of variety is really quite small.

Actually, engine *performance* not type is the factor that presents the average new car purchaser with distinctions he can appreciate—and performance is more closely related to engine displacement than to engine type. Because there is a wider range of displacements of such engines in U.S. built passenger cars, there is a more significant variety of engines here, I believe, than in foreign manufacture.

Finally, GM is planning to offer a new type of engine with introduction of the rotary engine to the marketplace during the 1975 model year. Also, we presently market a diesel automobile in Germany through our Opel Subsidiary and, as indicated in answer to Question 5 above, we are actively investigating the potential of the stratified charge engine.

For these reasons I believe the U.S. industry has been responsive to the U.S. marketplace and is offering a very wide range of vehicles and engines.

Very truly yours,

E. S. STARKMAN,
Vice President.

Mr. BROWN. I will adjourn the committee at this time and we will meet again tomorrow at 10 a.m. in this room to hear the testimony of representatives from the Eaton Corp., Scientific Energies Corp. and a private consultant, Mr. John W. Bjerklie.

The meeting is hereby adjourned.

[Whereupon, at 12:25 p.m., the subcommittee was adjourned to reconvene at 10 a.m., on Thursday, June 13, 1974.]

RESEARCH ON GROUND PROPULSION SYSTEMS

THURSDAY, JUNE 13, 1974

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to adjournment, in room 2325, Rayburn House Office Building, Hon. George E. Brown, Jr., presiding.

Mr. BROWN. The subcommittee will be in order. Chairman Symington will be delayed this morning, so we shall begin.

This is our third day of hearings in the current series on H.R. 10392, a bill to authorize NASA to conduct research on ground propulsion systems. Yesterday, we heard the testimony of top officials of the three major automobile manufacturers in this country. All three witnesses seemed to agree that the Government has a role to play in promoting research on automobile engines, although it is not conceived as a major role by any of them.

Chrysler would welcome NASA's interest in the automobile research with enthusiasm and hope, and would like to see NASA become involved in long-range basic research of the type the industry cannot afford to do. Ford sees a role for NASA in support of those Government agencies which already are charged with this mission. General Motors believes the automobile industry is equipped to respond to market trends without Government intervention but if there is to be Government research, it should concentrate more in fundamental areas and should supplement rather than duplicate the efforts of industry.

Today, our first witness will be Mr. Robert Richardson, manager of technological planning for the Eaton Corp. of Southfield, Mich., a major supplier of automotive parts and components.

Mr. Richardson recently published a report on future automotive powerplants.

Mr. Richardson, we are pleased to have you with us here this morning. I'm sure your statement will be a valuable addition to the record we are compiling on this important subject.

You may proceed.

[A biographical sketch of Mr. Richardson follows:]

MR. ROBERT W. RICHARDSON

Robert W. Richardson is Manager, Technological Planning for Eaton Corporation. His office is located in Southfield, Michigan. He was appointed to his present position in 1969.

The Technological Planning Department is responsible for organizing, supervising and conducting in-depth studies to identify long range new products and

new business opportunities for Eaton Corporation. Mr. Richardson recently led a team in a major study of future automotive powerplants.

His recent report has had wide distribution and he has made many oral presentations before various professional, business, technical and educational groups in the past year on the subject of future engines. He has previously conducted planning studies on various engines including turbine, steam and electric vehicles.

His study of *automotive safety* in 1964 led directly to Eaton's development of air bag passive restraint and truck skid-control systems.

Prior to joining Eaton in 1964 as a Research and Development coordinator, Mr. Richardson was Chief Mechanical Engineer for Simmons Precision Products, Inc.—a major manufacturer of gasoline fuel injection systems. His previous experience includes over ten years in design development, application and sales engineering on automotive gasoline injection systems with Simmons and General Motors Corporation.

Mr. Richardson holds four patents in the fields of air bag passive occupant restraint systems and fuel injection equipment.

Mr. Richardson has been active in the Society of Automotive Engineers as a participant and organizer of technical meetings on engines, pollution, energy and transportation. He currently serves as Vice Chairman of SAE's Advanced Powerplants Committee.

Mr. Richardson was born in Newton, Massachusetts in 1930. He received a B.S. degree in Mechanical Engineering from Massachusets Institute of Technology in 1952.

He resides with his wife, Jamae, and three children in Orchard Lake, Michigan.

STATEMENT OF ROBERT W. RICHARDSON, MANAGER, TECHNOLOGICAL PLANNING, EATON CORP., SOUTHFIELD, MICH.

Mr. RICHARDSON. Thank you, Mr. Chairman.

It is indeed a pleasure to be here and have this opportunity to appear before your subcommittee to discuss automotive engine R. & D. and the Government's role.

The proposed legislation, H.R. 10392, properly recognizes the need to meet four basic parameters simultaneously, energy conservation, emissions, producibility and cost. This represents a significant step in the right direction from earlier legislation which was aimed at a single parameter. Satisfaction of consumer needs require an often delicate balance between not only the four parameters mentioned but many others as well.

As you mentioned earlier, we have recently published a report on our in-depth planning study of future automotive engines. A copy of our published report is included for the record.

Mr. BROWN. Without objection, it will be included as part of the record.

AUTOMOTIVE ENGINES FOR THE 1980's—EATON'S WORLDWIDE ANALYSIS OF FUTURE AUTOMOTIVE POWER PLANTS

(By R. W. Richardson, Manager, Technological Planning, Eaton Corporation, Southfield, Michigan 48076)

ABSTRACT

There are five major contenders to replace or supplement today's piston engine. Changing social requirements and new technological developments Eaton feels will lead to major changes in automotive power plants. This study makes projections through the 1980's of the market penetration of Wankel, Stirling, turbine, stratified charge and diesel engines for passenger car, heavy duty and small engine applications. These engines are compared on the basis of ten major selection parameters. Major factors affecting the rate of commercialization of

new engines are reviewed including social, political and economic forces of change and historical perspective. Major inputs came from more than 60 worldwide in-depth interviews.

I. INTRODUCTION [1]

Never in the history of the automotive engine have there been so many serious contenders and never with so great a chance of replacing or supplementing the piston engine. While the piston engine has for many decades served its hundreds of millions of users well and is continuing to serve them well, its noise, exhaust emissions and more recently its fuel appetite have come under attack.

The purposes of the basic study upon which this report is based were to assess these various new engine types, determine their market applicability and likely commercialization through the 1980's and provide broad overall perspective on the future of automotive engines.

Major inputs for the study were obtained from over 60 in-depth interviews worldwide. These included car and truck manufacturers; heavy duty and small engine producers; developers of new engines; materials, parts, fuels and lubricants suppliers; machine tool builders; government agencies; trade associations; independent research institutes and consultants. These inputs were combined with business, technical and historical analyses and an evaluation of the social, political and economic forces that cause change.

While the study was conducted for internal purposes, the conclusions and projections reached have far-reaching implications of wide interest. Therefore, it was decided to publicise those portions of the study that cover the significant non-proprietary findings and projections. In the study, primary emphasis was placed on the Wankel engine and on those factors which will have the greatest bearing on its (degree and rate of) commercialization. Priority was placed on passenger car application followed closely by heavy duty markets with a relatively modest effort in the small engine area. This report, therefore, was compiled with a similar emphasis.

II. ENGINES AND APPLICATIONS

The engines that are now used and those which warrant and/or are receiving serious attention for three broad areas of application—small engines, passenger cars and heavy duty—are listed in *Table 1*. The passenger car area has the most

Candidate Alternate Powerplants by Market

	Small Engine	Passenger Car	Heavy Duty
NOW	2-Cycle - 4-Cycle	4-Cycle	Diesel
FUTURE	Rotary Turbine	Rotary Turbine Stirling Stratified Charge Diesel	Turbine Stirling

TABLE 1

[1] This report is based on a recently conducted major technological planning study. In addition to the author, the research team included L. F. Jenkins of Eaton's Valve Division, and R. P. Horan and R. L. Martin of Eaton's Technological Planning Department. The four team members were all automotive engineers having a combined experience in excess of 80 years directly on automotive products—primarily engines and engine components. The majority of this experience has been with new product development and commercialization. The team members also had nearly 30 years combined experience in making in-depth technological planning studies.

Scale side view drawings showing engine and drive trains of various foreign and domestic automobiles have been reproduced from Road & Track magazine by permission of Bond/Parkhurst Publications, a unit of CBS Publications.

contenders. Electric and steam vehicles have not been included as serious contenders for high volume applications as a result of Eaton's previous in-depth investigations.

Like the piston engine, these new engines come in a wide variety of broad configurations and subtypes. The type or configuration of each engine believed best suited for each application has been used in the comparative evaluation for that application.

These different powerplants are all in various stages of development (*Figure 1*) which has a bearing on the ability to assess accurately the various parameters

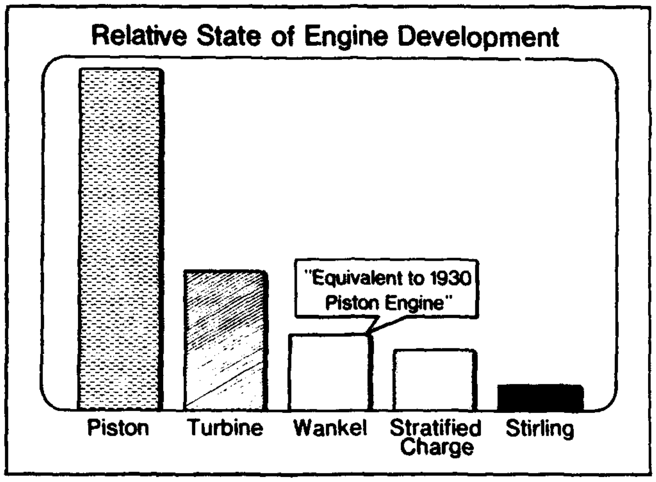


FIGURE 1

important to engine selection: factors such as fuel consumption can be accurately determined but production cost or durability are little more than guesses at an early stage of development. Engines at an early state of development are also much more susceptible to rapid improvement than mature engines.

III. DESCRIPTIONS & STATUS OF ENGINE TYPES

Rotary (Wankel)

The Wankel engine is a four-cycle spark ignition internal combustion engine differing from present engines primarily in mechanical design. It uses a "rotating" (epitrochoidal) motion rather than a reciprocating motion. It uses ports rather than valves for controlling the intake of the fuel-air mixture and the exhaust of the combusted charge. In this respect it is similar to a two-cycle engine.

The Wankel has been under development since its invention in the early 1950's. NSU (West-Germany) introduced a single rotor powered car in 1964 and a two rotor powered car in 1966. Neither engine has been built in significant volume. Toyo-Kogyo (Japan) introduced a two rotor engine in their Mazda cars in the late 1960's and are now producing about 20,000 models per month. 50,000 of these were sold in the U.S. last year.

Snowmobiles with a Fichtel and Sachs single rotor Wankel have been sold for the past four seasons. Similar engines are being used in power lawn mowers. Outboard Marine Corp. last year introduced their Wankel snowmobile and has outboard versions under development. A number of major firms throughout the world own a Wankel license and several—most notably General Motors—are aggressively pursuing its development. GM plans to introduce it as an option in the Vega in the summer of 1974.

Turbine

The gas turbine engine is a continuous flow, continuous internal combustion, high speed engine utilizing aerodynamic compression and expansion rather than positive displacement. The turbine uses no valves or ports. The engine requires a number of parts made from high temperature alloys.

The gas turbine has been under development since the 1930's. It has found ready acceptance in aircraft and is now nearly universally used except below 500 HP. The auto industry has been working on turbine power for nearly 25 years. Exotic show cars have been produced from time to time. About 10 years ago, Chrysler produced 75 special turbine powered cars for field testing. Most of the industry's effort has since then been directed at truck and industrial applications. Both GM and Ford have produced pilot quantities of an industrial engine of about 300 HP. Ford has recently closed down their pilot operation to await a major product redesign abused at the late 1970's. The big three all are reported to have substantial passenger car turbine development programs. The Environmental Protection Agency is funding part of Chrysler's program and also passenger car turbine development by several aircraft engine producers.

Stirling

The Stirling engine is an external continuous combustion engine utilizing positive displacement piston compression and expansion. It utilizes a sealed high-pressure working fluid (hydrogen or helium) and operates at relatively low speed. High temperature alloys are required for the combustor-to-working-fluid heat exchanger (heater head).

The Stirling was invented in 1816 and saw service as a pumping engine in mines during the 19th century. These engines used air at low pressure as the working fluid. The modern Stirling engine dates from the late 1930's based on work by N. V. Philips in the Netherlands. In recent years, considerable progress has been made in refining the Stirling engine.

Philips has licensed other developers. During the 1960's GM was Philip's major licensee, accumulating more than 25,000 hours of engine operating experience in their development program. GM allowed their license to lapse in 1970, however. More recently (1972) Ford Motor Co. was licensed by Philips. They are jointly working on passenger car prototypes. Philips has also licensed United Stirling in Sweden and MAN in Germany. United Stirling has been a major contributor to recent progress and is also working on passenger car applications. Both Philips and United Stirling have made recent prototype bus installations.

Stratified Charge

The stratified charge or hybrid engine is a variant of conventional engines combining features of both gasoline and diesel engines. It differs from conventional gasoline engines in that the fuel-air-mixture is deliberately stratified so as to produce a rich mixture at the spark plug while maintaining an efficient and cleaner burning overall lean mixture and minimizing or avoiding the need for throttling the intake air.

Stratified charge development dates back at least to the work done by Ricardo in England during World War I. Since that time, many inventors and developers have worked with various concepts. Substantial work has been done in Russia and the U.S. over the past 15 years. More recently, the Japanese, especially Honda, have made major contributions to the state of the art. The Honda CVCC engine meets the original 1975 emission standards without hang-on controls. Ford and Texaco have done substantial work on concepts quite different from Honda's.

Diesel

Diesel engines are quite similar to gasoline engines but use fuel injection directly into the cylinder rather than a carburetor. They have no ignition system as such, relying on very high compression to cause the mixture to self ignite.

Diesel engines have been widely used in heavy duty applications for decades. They are also used to limited extent on passenger cars mainly in Europe. Mercedes has long produced a low performance diesel car. More recently, Peugeot and Opel have been building diesel cars. Many are used for taxis. Austin (BLMC) also builds diesel taxis. The engine has not been seriously considered for passenger cars in the U.S. until recently. The Environmental Protection Agency is expected to award a study contract in near future for a passenger car diesel engine.

IV. ENGINE SELECTION PARAMETERS

Table II lists the more significant engine selection parameters. They are all self-explanatory except for flexibility which means performance flexibility or torque-speed characteristics as they relate to transmission requirements and

Engine Selection Parameters

TRADITIONAL	NEW
Cost	Emissions *
Durability - Life	Noise *
Weight	
Size	
Smoothness	
Flexibility	
Maintenance	
Fuel Consumption *	

* Social Requirements

TABLE II

driveability. The parameters listed on the left are traditional ones. On the right, two new parameters are listed which are primarily social requirements. Fuel consumption has also been labeled a social requirement because of the energy crisis—it has long been an economic or logistic requirement.

Some idea of the changing relative importance of the social requirements can be gained from *Table III*. They have been rated on a 0–10 scale to provide helpful perspective. Only a slight lessening in absolute importance of emissions (assuming no major air pollution disasters) is expected—some increase in the impor-

Relative Importance of Social Requirements

	Aug 72	Feb 73	1975	1980	1985
Emissions	7	7	6	6	6
Noise	3	3	3	4	4
Energy Resources	1	3	5	10	7

TABLE III

tance of noise and a tremendous increase in the importance of fuel consumption—becoming half again as important as emissions before the end of this decade. A two to three fold increase in gasoline prices and national rationing within the next few years seem likely.

Today, of course, as the chart shows, emissions are more important. There is wide speculation on Congress revising the very stringent 1975–76 standards to achieve a better balance between society's needs for acceptable cost and fuel consumption as well as emisisons.

The significance of the emission levels which are ultimately selected is their great bearing on both absolute and relative cost and fuel consumption of different engines. As emissions are reduced, both cost and fuel consumption tend to

increase for all engine types. They are likely to increase, at markedly different rates, however, for different engines. For example, a low-cost conventional piston engine may require a very-expensive precious-metal dual-catalyst to meet a tight standard while a somewhat more complex and costly stratified charge engine, such as the Honda, may require no extra emission controls.

V. SELECTION PARAMETERS & COMPARISON OF ENGINE TYPES

Three areas of application have been considered: passenger cars, heavy duty and small engines. Obviously, the priority of selection parameters differs somewhat in each of these three areas.

A. *Passenger Cars*

Taking passenger car applications first, the selection parameters fall into the order of relative importance shown in *Table IV* with flexibility, smoothness and emissions leading the list, and maintenance, fuel consumption and durability on the bottom. This ranking is for 1973 values. The arrows on the left show both noise and fuel consumption rising to expected 1980 positions. This order of importance of parameters is for the broad passenger car market. Obviously, there may be segments of this market which would have somewhat different orders of

Relative Importance of Selection Parameter

Passenger Cars — Compared with 4-Cycle Spark Ignition Piston Engine

	Wankel	*Turbine	Stirling	Stratified Charge	Diesel
Flexibility	–	+	+	0	–
Smoothness	+	++	++	0	–
Emissions	0	+	++	+	+
Cost	–	–	–	?	–
Noise	0	+	++	0	–
Weight	+	+	0	–	–
Size	+	0	–	–	–
Maintenance	0	+	+	0	+
Fuel Consumption	–	–	++	+	++
Durability	–	?	+	0	+

Advantage (+) or Disadvantage (–) *Two-Shaft Regenerative 1900 F Turbine Inlet Temperature

TABLE IV

importance. The five new engine types competing for future automotive use are compared with the 4-cycle, spark ignition piston engine on each of these parameters. Each engine was rated better (+), worse (–), or equal (0) to the present gasoline engine.

Wankel

(1) *Flexibility.*—Wankel engines tend to have lower torque at low speeds and a higher speed for their torque peak than reciprocating engines. This means that the rotary engine has reduced performance flexibility requiring more shifting or more sophisticated transmissions for equivalent performance.

(2) *Smoothness.*—A single rotor Wankel can be equal to or better than many 4-cylinder engines, while a two rotor Wankel is smoother than 4- or 6-cylinder engines. Most interest has been generated for two rotor Wankel engines with only little interest in three or four rotor engines and very little interest in single rotor engines.

(3) *Emissions.*—Untreated, the Wankel is a rather dirty engine with emissions of hydrocarbons as much as five times higher, carbon monoxide up to three times higher while oxides of nitrogen are up to 75% less. Derating a conventional engine to the same level of efficiency would be expected to result in similar emission levels. Conversely as the Wankel seals are improved, oxides of nitro-

gen will tend to increase and hydrocarbons decrease. The Wankel has fewer exhaust ports and, because it is less efficient, operates with a higher exhaust temperature which makes thermal reactors more applicable.

(4) *Cost.*—Although the Wankel uses fewer parts and is lighter, even when built in high volume, it costs more than a piston engine. It will likely be more expensive for some time to come; however, with substantial product and manufacturing development effort, it could ultimately become cheaper to produce. (The cost is discussed in more depth in Section VIII.)

(5) *Noise.*—The elimination of mechanical moving parts, such as the valve gear, should reduce noise but data on the limited car (and snowmobile) models available show approximately equal noise levels.

(6) *Weight.*—Wankel engines weigh less, especially when only the basic engine structure is compared. When completely equipped with all accessories needed for operation, there is a smaller relative advantage as these accessories are essentially equal or occasionally heavier.

Wankel weight savings of 50% are often claimed. Realistic comparison shows must less. Comparison of the lightest experimental Wankel known with the lightest production piston engines indicates 12–16% weight savings on a pounds per horsepower basis. (These engines are not of equal horsepower). Karl Ludvigsen, in a recent article in *Road Test* magazine, indicates an average weight savings of 11% comparing several pairs of engines of equal performance. Significant reductions in average weight and size of piston engines are possible should this become a high design priority. (Weight is further discussed in Section VI.)

(7) *Size.*—Wankel engines also have a size advantage usually somewhat greater than their weight advantage. Most of the comments on weight (above) also apply here. Comparing the lighest and most compact engines shows size advantages in the range of 34–45% based on a "box" volume (max. length × max. height × max. width). Karl Ludvigsen's analysis indicated a 30% average advantage. (The significance of weight and size savings as it relates to packaging in an automobile is discussed in Section VII.)

(8) *Maintenance.*—The maintenance requirements of the Wankel are expected to be reasonably comparable to the piston engine. The Wankel has fewer but more complicated and expensive parts. It uses similar types of fuel, air cleaning, ignition, cooling and exhaust systems. Wankels currently use a more complex emission control system requiring more maintenance.

The Wankel can provide some savings through longer oil change periods. A recent survey indicates tune-up costs at dealers are approximately equal for Mazda and V8 engines. Fours and sixes cost less to tune up of course.

(9) *Fuel Consumption.*—Fuel consumption includes both quantity and quality of fuel. Wankel engines have substantially higher fuel consumption: 30–40% higher (or 25–30% fewer miles per gallon) than piston engines. At very low emission levels, this difference will probably be reduced but not eliminated. Improved seals will also help reduce, but not eliminate, this fuel consumption penalty as the combustion chamber appears inherently less favorable. In contrast to its higher use of fuel, the Wankel has a requirement for lower octane quality (low to mid-80's for Mazdas). The octane requirement will probably increase as seals are improved and as the engine is scaled up to larger displacement per rotor.

(10) *Durability.*—The durability of Wankel engines was initially very poor. The Mazdas have substantially better durability but are not yet up to typical U.S. standards. Compatible trochoid surface materials and treatment, together with seal materials having very long life, have been developed but apparently not with acceptable cost and sealing characteristics.

Based on this somewhat superficial comparison, weighted for importance of parameters, the Wankel appears to have little, if any, net advantage. As the fuel consumption issue takes on more importance, the Wankel's competitive position will be more tenuous. If manufacturing cost breakthroughs are achieved, it may still find a substantial niche.

Turbine

(1) *Flexibility.*—Two-shaft turbines have a very favorable torque curve having in effect a built-in torque converter. Single shaft-engines which have recently come under serious consideration have an unfavorable torque curve.

(2) *Smoothness.*—As a continuous fluid flow rotary machine, the turbine is extremely smooth.

(3) *Emissions.*—Turbine combustors can be built which have very low emissions, especially of hydrocarbons and carbon monoxide. There is some question as to whether they can meet the pending 1976 NO_x standard of 0.4 grams/mile.

(4) *Cost.*—Turbine engines require the use of substantial amounts of expensive, difficult to fabricate superalloys and an expensive regenerator. Potentially possible, but requiring a great development effort, is a simpler turbine operating at higher pressure ratios and temperatures using lower cost ceramic materials. Such an engine could ultimately be cheaper than the piston engine, Single-shift engines cost significantly less than two-shaft, but require more sophisticated and costly transmissions.

(5) *Noise.*—Despite the image of turbine powered aircraft, the turbine engine is relatively easy to silence.

(6) *Weight.*—Turbine engines are substantially lighter than piston engines.

(7) *Size.*—The basic turbine is also substantially smaller than the piston engine but the addition of a regenerator results in no net size advantage.

(8) *Maintenance.*—The turbine is basically a simple machine and, with freedom from vibration, should have lower maintenance.

(9) *Fuel consumption.*—The turbine has higher fuel consumption, especially at light loads typical of much automobile operation. At very tight emission standards, the fuel consumption increase of piston engines could result in the disadvantage of the turbine being eliminated. Development of materials allowing operation at higher temperature would help make the turbine competitive on fuel consumption. The turbine is capable of operating on a wide range of fuels, but specific designs require a limited range.

(10) *Durability.*—Aircraft turbine engines have demonstrated much greater durability than piston engines. There is considerable doubt, however, whether this will be true for cars due to operation with very frequent wide fluctuations in load and operation with dirter air. The addition of the regenerator required for reasonable part load fuel consumption may also reduce durability.

Overall, the turbine appears to have a significant potential net advantage and apparently warrants additionl development effort.

Stirling

(1) *Smoothness.*—Stirling engines are also extremely smooth engines effectively completely balanced and have very minor cyclical variations in torque.

(2) *Flexibility.*—The Stirling engine has a favorable torque curve providing substantial torque increase as speed falls.

(3) *Emission.*—The Stirling, based on bench tests, appears to have the lowest emissions of all known engines, well within 1976 requirements—achievable with little penalty in fuel consumption or cost.

(4) *Cost.*—The Stirling appears to have a cost disadvantage due to the requirement for high temperature alloys in the heater head and to control problems. Recent developments indicate these control problems are not as formidable as once believed. At very tight emission standards, the piston engine could conceivably increase sufficiently in cost to make the Stirling competitive or possibly give it an advantage.

(5) *Noise.*—The Stirling engine has a very low noise level and is the quietest of any of the serious contenders.

(6) *Weight.*—Recently developed double acting Stirling engines appear competitive in weight.

(7) *Size.*—Stirling engines are somewhat larger than piston engines but studies show they can be installed with all accessories in engine compartments of both sub-compact and full size cars.

(8) *Maintenance.*—Like the turbine, the Stirling should have relatively low maintenance requirements.

(9) *Fuel Consumption.*—The Stirling has a fuel consumption potential lower than any other contender and will operate on the broadest range of fuels. Achievement of the very low fuel consumption may not be possible with a practical size radiator. Compromise would still leave the engine with lower fuel consumption than any engine but the diesel.

(10) *Durability.*—Developmental Stirling engines have shown extremely high durability—perhaps due to over-design. Some compromise to help reduce cost may be in order.

On balance, the Stirling engine appears potentially the most attractive powerplant over the long range.

Stratified Charge

(1) *Flexibility.*—The stratified charge engine can equal the flexibility of the piston engine, although it is difficult to achieve. It may not be achievable on all types of stratified charge engines.

(2) *Smoothness.*—The stratified charge engine as a modification of the gasoline engine should have approximately equal smoothness.

(3) *Emissions.*—Stratified charge engines have shown potential for low emissions. Honda has readily met the original 1975 standards with both small and large cars and has come close to 1976 standards with small cars. Other types of stratified charge engines, such as the Ford Proco have shown potential for relatively low emissions (but not yet as good as Honda).

(4) *Cost.*—As there will probably be some loss in maximum power and some increase in complexity (prechamber 3rd valve or fuel injection), some increase in cost over present (1973) engines is likely. However, compared to dual catalysts, it would likely be substantially cheaper.

(5) *Noise.*—Noise should be equivalent.

(6) *Weight.*—Due to some probable loss in maximum power, relative weight would slightly increase.

(7) *Size.*—The same applies for size as for weight.

(8) *Maintenance.*—Stratified charge engines should require slightly more maintenance than uncontrolled engines—somewhat less maintenance than engines with dual catalyst.

(9) *Fuel Consumption.*—Probably a slight advantage in fuel consumption will be realized by practical stratified charge engines although development will be required. Burning of overall lean mixtures and reduced pumping losses both save fuel. Stratified charge engines can use a broader range of fuels.

(10) *Durability.*—Based almost exclusively on current piston engine technology, the stratified charge engine's durability should be similar.

The stratified charge engine, on balance, is not as attractive as the Stirling, but because it is based largely on existing parts, it could be commercialized relatively rapidly with only slight disruption to the industry. It is only marginally attractive compared with current engines. It is quite attractive, however, compared to conventional engines with dual catalyst.

Diesel

(1) *Flexibility.*—Diesel engines generally operate over a narrower speed range and require more gear ratios and shifting.

(2) *Smoothness.*—The diesel is less smooth than the gasoline engine due to its combustion characteristics.

(3) *Emissions.*—Diesel engines have very low hydrocarbon and carbon monoxide emissions and can have fairly low oxides of nitrogen emissions but probably not low enough to meet 1976 requirements. Diesel engines, however, also tend to produce objectionable smoke and odor.

(4) *Cost.*—Because of the direct fuel injection system (15-25% of engine cost) and because of the requirement for a more rugged structure, diesel engines are substantially more costly.

(5) *Noise.*—Diesel engines are generally much noisier.

(6) *Weight.*—Unless the diesel were turbo-charged to a high boost-pressure and run at high speed, it would be substantially heavier.

(7) *Size.*—The same applies for size as for weight.

(8) *Maintenance.*—Diesels have proven to have low maintenance requirement primarily due to their heavy rugged design.

(9) *Fuel Consumption.*—The diesel is a very efficient engine and has a substantial fuel consumption advantage especially at light loads characteristic of passenger cars.

(10) *Durability.*—The diesel has also been proven to be a very durable engine also due to its rugged design.

On balance, the diesel does not appear to be an attractive alternate for passenger cars.

Stratified Charge Wankel

Much has been made recently of the potential for a stratified charge Wankel. Operating on the same thermodynamic principle as the piston engine, it is possible to produce stratified charge Wankel engines. Because of the gross mechanical design differences in the two engines, it is usually not possible to have exactly equivalent stratification approaches. The development of a strati-

fied charge Wankel represents a greater technical challenge than development of the conventional Wankel and therefore appears to be further away. Stratification should have relatively the same advantages and disadvantages as it does for the piston engine although due to the specific designs evolved, their relative costs might be quite different.

B. Heavy Duty

For heavy duty applications, the parameters have been reordered (*Table V*) with fuel consumption, maintenance and durability moving from least important to most important, flexibility and smoothness move from most important to near least important. The basic engine for comparison is the diesel engine.

Relative Importance of Selection Parameter

Heavy Duty Applications	Compared With Diesel Engines: Wankel	Turbine*	Stirling
Fuel Consumption	−	−	+
Maintenance	−	+	+
Durability	−	?	+
Emissions	−	0	+
Noise	0	+	++
Cost	?	−	−
Smoothness	+	++	++
Flexibility	0	+	+
Weight	+	+	+
Size	+	0	0

Advantage (+) Or Disadvantage (−) *Two-Shaft regenerative 1900 F Turbine Inlet Temperature

TABLE V

The Wankel engine considered here is substantially different from the passenger car Wankel. The high compression ratio required for diesel compression ignition results in very unfavorable geometry in a Wankel. Engines of this type have been built but performed very unsatisfactorily. This problem can be overcome by compounding two stages of lower compression. Rolls Royce is the apparent leader with this approach. The two-stage Wankel diesel is in a much earlier state of development and the problems to be overcome are greater. It has the disadvantage of adding complexity but still results in a very compact engine. The Wankel requires only one fuel injector for each two-stage unit. This version will probably be built primarily with two two-stage units. The two fuel injectors required compare with 6 or 8 on a piston type diesel engine. Fuel injectors must operate at twice the frequency at the same engine speed and as the speed of the Wankel is higher than the piston engine, the maximum frequency of injection is much higher. Injection equipment to operate at these frequencies has not yet been developed.

While this type of Wankel has advantages compared with piston diesels, they are in the least important parameters. It has disadvantages in the most important parameters. The Wankel, therefore, looks unattractive for heavy duty application.

Both the turbine and Stirling not only appear far more attractive than the Wankel, but also offer advantages over the diesel. The turbine's high fuel consumption may, however, prevent it from achieving substantial acceptance. The Wankel diesel might have potential for medium duty applications where fuel consumption, maintenance and durability are of lesser importance.

C. Small Engines

Small engines are used in a wide variety of applications such as chain saws, lawnmowers, generator sets, pumps, and recreational vehicles and low-power industrial vehicles. The requirements of these engines can vary significantly. For purposes of analysis here, the parameters have been placed in order of importance for consumer product applications (*Table VI*). Both two- and four-cycle piston engines are used for these products. The two-cycle engine is predominant at the higher power levels of most recreational vehicles. It has, therefore, been chosen as the base engine.

Relative Importance of Selection Parameter

Small Engine Applications	Compared With 2-Cycle Spark Ignition Engine: Wankel
Cost	–
Weight	–
Size	0
Flexibility	+
Smoothness	+
Noise	+
Emissions	+
Maintenance	+
Durability	–
Fuel Consumption	+

Advantage (+) or Disadvantage (–)

TABLE VI

Wankel engines for this application would be primarily single rotor and would use charge cooling of the rotor instead of oil cooling and would use an oil-fuel mix similar to many two-cycle engines.

There appears to be no way the Wankel can ever be cost competitive with single cylinder piston engines. Although Wankels are offered in snowmobiles, outboards, lawn mowers and for model airplanes, they are sold to a very limited market at very substantial premiums. The Wankel has a better chance against multicylinder engines (above 15 HP). As the products using small engines become subject to more stringent noise and emission regulation, the cost, size and weight of the piston engine will rise faster than for the Wankel, perhaps making it competitive. The Wankel has advances in all the other parameters except durability which is relatively unimportant. The Wankel, therefore, looks promising for recreational vehicles especially those now using multi-cylinder engines.

VI. PASSENGER CAR ENGINE PACKAGING

Size, weight, and configuration of engines are significant factors in engine installation and vehicle layout. The piston engine is being used in a wide variety of vehicle configurations today—front engine, rear engine or mid-engine; longitudinal or transverse mounting; and with front or rear drive. Size and weight of engines have been relatively unimportant (ranked 6th and 7th of ten parameters) in the past but are expected to become increasingly important due to the trend toward smaller cars and the increase in space requirements and weight of emission control and safety equipment. The "energy crisis" will further increase the importance of size and weight.

Major factors behind projections of a rapid Wankel revolution are claims of savings of 50% or more in engine size and weight. These savings are projected to be further amplified through the redesign of passenger cars permitting a net reduction in car length of 30 inches without sacrificing passenger space due to the smaller engine. This reduction in length, together with the lighter engine, has been projected to result in a total weight reduction of 1,000 lbs, together with consequent cost savings.

Wankel proponents claim that these goals can be reached by placing the engine across the front of the car using front wheel drive—a so called transverse engine. Indeed, the claimed weight and size advantages for the Wankel are considered so compelling to both user and manufacturer as to cause a rapid changeover to the Wankel engine for economic and competitive reasons.

Extensive analysis of size and weight of the Wankel engine, however, reduced this claimed advantage somewhat as discussed previously (Section V). Weight savings of 10–20% and volume savings of 30–40% seem reasonable. These still represent substantial improvements, especially in volume. However, these volume savings are not so readily converted to major reduction in vehicle size. The volume comparisons are based on the box created by multiplying the maximum width, height and length. Most piston engines do not fill the box very completely, as the picture of the Pinto engine shows (*Figure 2*). Within the maximum width,

FIGURE 2

there is considerable space at the upper left for accessories and lower left and right for frame rails, running gear, suspension components, or emission controls.

In contrast, the Wankel engine is indeed very compact but much more nearly fills its box as the picture of the Mazda shows (*Figure 3*). This Mazda engine is both somewhat lower and shorter than the Pinto engine but not narrower.

In the Toronado front wheel drive care (*Figure 4*), the transmission and differential are placed along side the engine adding only slightly to width and height of the engine "box". This is the type of arrangement which would also be used with a transverse installation. Packaging a transmission and differential with a Wankel engine would add significantly to the width and/or height of the installed Wankel engine box.

Considerable length saving can be achieved with present engines (*Figure 5*). The 1972 LTD shown here has more than 18 inches of unutilized or poorly utilized space ahead of the engine. Some cars have even more waste space. Since the time the stylist hid the radiator, more than 40 years ago, unused or poorly utilized

FIGURE 3

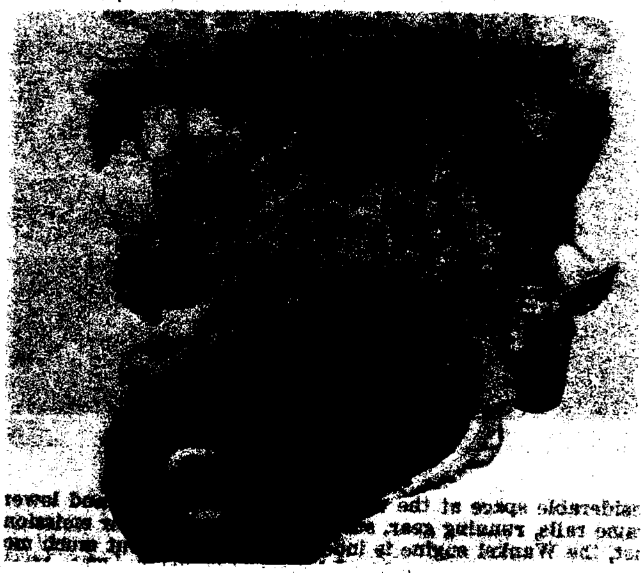


FIGURE 4

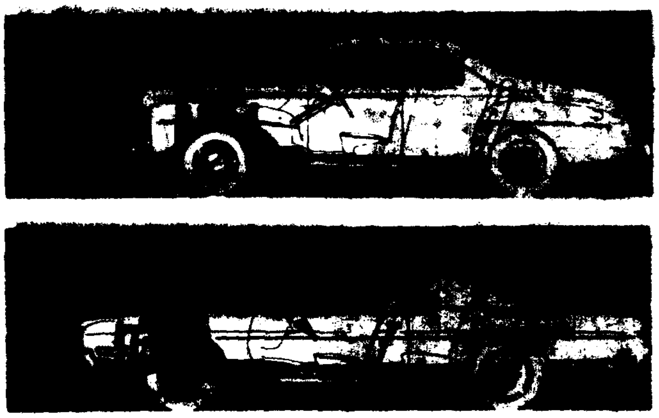


FIGURE 5

space in front of the engine has been the rule. The '47 Ford had about 14". A number of [illegible] from in-line 8-cylinder [illegible] considerably in engine length, but their cars did not get shorter or the [illegible] compartment bigger—in fact the reverse was true. While space is present in [illegible] and compact cars and also in many foreign cars.

Perhaps the best example of a very effective packaging job is the family of cars BMC introduced in 1959 (*Figure 6*). The [illegible] cubic inch displacement (C.I.D.)

FIGURE 6

Mini was followed shortly with the 67 C.I.D. MG and then the 110 C.I.D. Austin America, all with transverse engine front wheel drive. More recently, a 130 C.I.D. transverse 6-cylinder model has been produced. Within the same width, which is 12" narrower than full sized U.S. cars, it would be possible to put a 272 C.I.D. V-12 engine—a V8 of the same length (car width) and having same B/S ratio could be as large as 615 C.I.D.—nearly 20% larger than the largest car engine in production. These very compact vehicles did not, however, have such compelling advantages as to cause a massive switch to this concept.

These transverse engine cars are no longer imported into the U.S., having been replaced by a conventional front engine rear drive model. Nevertheless, others have adopted the concept including Peugeot and Fiat (*Figure 7*). The Japanese appear to have carried the concept to its extreme (*Figure 8*). The 36 C.I.D. Honda

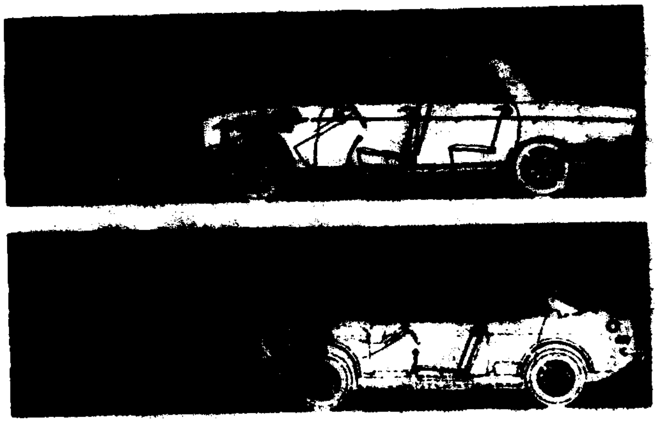


FIGURE 7

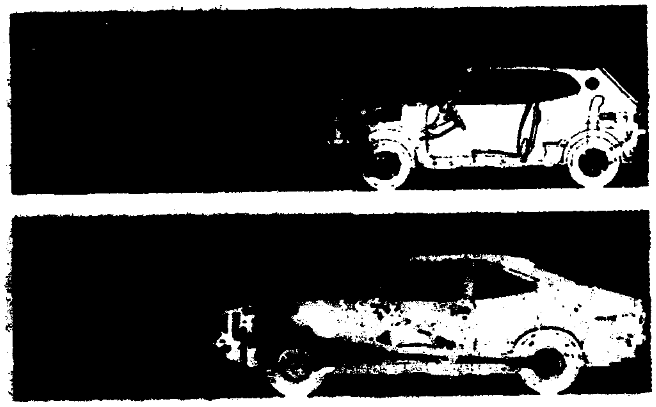


FIGURE 8

600 coupe is at the top, one of the smallest cars sold in recent years in the U.S. Smaller cars are sold of course in Japan.

Shown below is the Toyo Kogyo Mazda RX3 with the Wankel engine in a conventional rear drive arrangement. Another version of the Mazda, the RX2, is shown at the top of *Figure 9*. Recently introduced in the U.S. is the Honda CIVIC model with a 72 C.I.D. engine. It is this car in which a 110 C.I.D. CVCC stratified charge engine (which meets the '75 emission standards) has been installed.

There appears to be no way the Mazda engine could be fit, regardless of position, in the space available in the Honda, Fiat, Peugeot or BLMC cars without increasing the vehicle length. There appears to be no substantial packaging advantage in conventional configuration either, at least against 4-cylinder engines. Significant length savings could be achieved compared with a 6-cylinder engine, however. One Wankel disadvantage with *front* engine rear drive also shown in *Figure 9* is the higher driveshaft requiring a higher tunnel through the car. This is due to the centerline of the Wankel rotor shaft being significantly higher than a piston engine crankshaft.

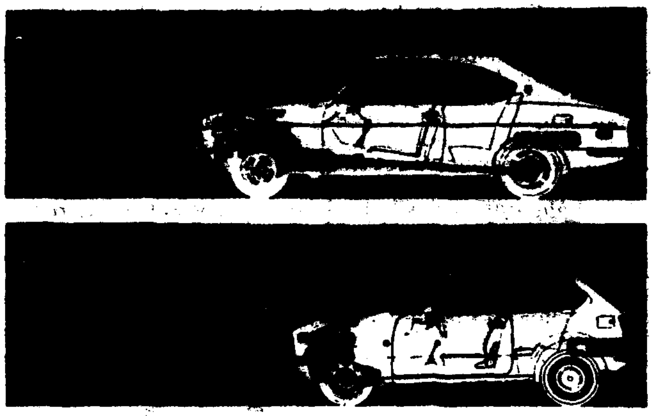


FIGURE 9

These silhouettes indicate that major reductions in the size of piston powered cars are achievable. The volume savings of the Wankel are simply not capable of being converted to substantial additional savings in size, weight or cost. Furthermore some of the realizable weight saving of the Wankel is due to the substantial use of aluminum at 30-35¢/pound versus cast iron in the piston engine at 7-8¢/pound.

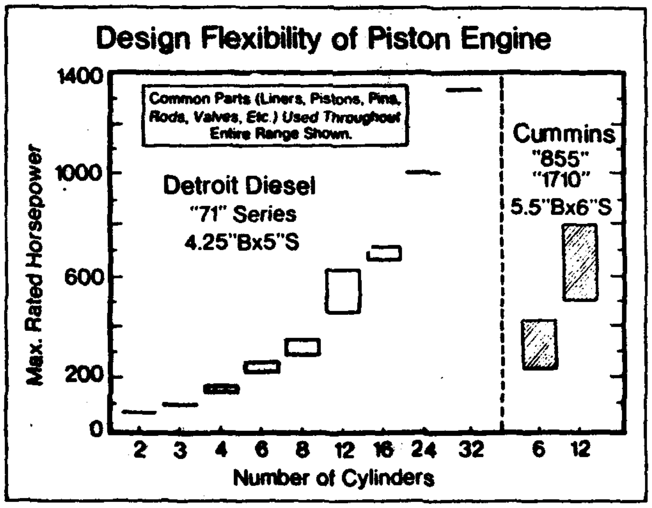


FIGURE 10

VII. DESIGN FLEXIBILITY

Much has been made of the design flexibility of the Wankel—allowing any number of rotors to be "stacked" allowing common tooling to provide for a very wide range of power needs. There is very little interest in single rotor engines for passenger cars so the minimum engine became a two-rotor engine. Three and four-

rotor engines have been built, but there is a cost penalty of a two-piece rotor shaft and coupling or a split gear and housing to allow more than two rotors to be assembled. [illegible] a second split. Wankel rotors may be [illegible] in-line only, [illegible] shafts and additional gearing or [illegible] design. In contrast, [illegible] may be arranged in-line, vee, or opposed configurations and in-line engines may have their cylinders mounted horizontally, vertically or slanted as needed to fit a variety of applications.

The turbine engine has even less design flexibility than the Wankel. The Stirling engine can have design flexibility equaling the piston engine but economics may reduce this flexibility potential somewhat.

This design and application flexibility is very important to the relatively low volume producer. Using a large number of common parts, a wide range of power needs, from [illegible] HP, can be covered with one cylinder size by Detroit Diesel by varying the number of cylinders (*Figure 10*). Cummins covers a range of 200 to 800 HP using one cylinder size with only 6- and 12-cylinder engines. This flexibility allows engines to be designed specifically for some very low volume applications, but still at a reasonable cost.

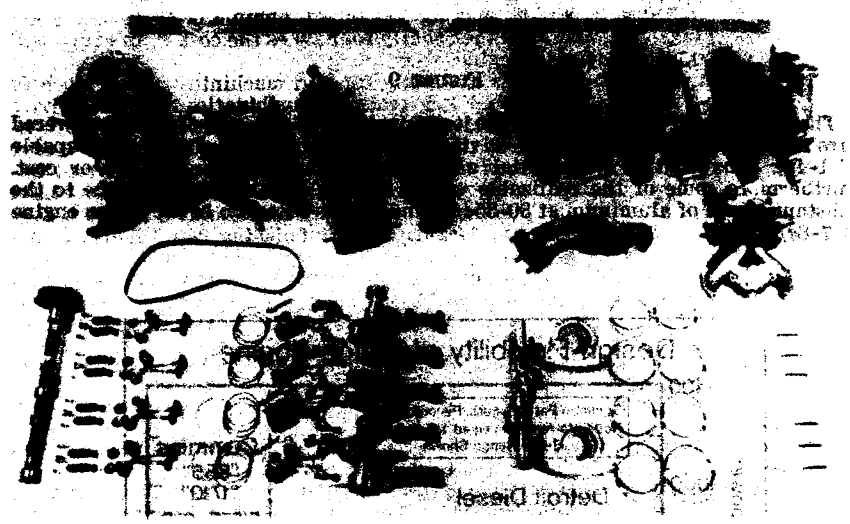


FIGURE 11

VIII. COST

Cost is the greatest unknown factor and will probably have the most influence upon the applicability and rate of commercialisation of new engines. Cost is a function of weight, number of parts and technological density. The latter concept comes from Mr. Yamamoto of Toyo Kogyo. Technological density includes materials, quantity and quality of machined surfaces, tolerances, surface treatments, and design complexity. Most cost projections are superficial, being based on the first two terms only.

This is a widely used preliminary estimating approach and is valid when the third term is relatively equal, but in the case of at least Wankels and turbines, which do weigh less and have fewer parts, it is not. *Figure 11*, comparing a Pinto four-cylinder with a Mazda two rotor Wankel, does show fewer pieces but not dramatically less as some comparisons have. In this illustration, the Wankel uses 42 sealing elements per rotor (other configurations use up to 58 per rotor). In contrast, the piston engine uses only five per cylinder. Including the valve gear parts and the seals, the piston engine uses only 19 per cylinder. The piston engine has the advantage that most are duplications of simple parts produced in high volume—eight of each valve gear part (16 each on an 8-cylinder engine).

In contrast to the piston rings, which are self-retained in place, Wankel seals are held in place only by gravity or friction with the seal springs trying to eject them. This suggests some difficult assembly problems not readily lending themselves to economical automation.

The only examples of production Wankels, whether in cars, snowmobiles or model airplanes, currently sell for high premiums. Mazda sells for a $600 premium here and more than a $300 premium in Japan where the thermal reactor emission controls have not been used. Mazda's cost penalty is not known but believed to be substantial. While Mazda's volume is low (156,000 Wankels/yr) compared to the highest volume U.S. engine, it is not low compared with their piston engine production: in 1972 it accounted for 40% of passenger car production. It is actually comparable in volume to many U.S. engines including Chevrolet, AMC or Ford 6's, AMC 8's and several other 8's.

Since the Wankel's introduction in 1967, Toyo Kogyo sales have more than doubled but their profits have steadily declined. Their average retail premium worldwide was about $400 last year and with normal discounts, about $250 per car was received by Toyo Kogyo. It appears most of this premium is eaten up in higher costs.

U.S. snowmobiles with Wankel engines sell for a premium of from $160–$350. A small model airplane engine sells for nearly four times the cost of an equivalent two-cycle piston model airplane engine.

One of the areas of high cost is materials for and machining of the trochoid surface. While a great many material and treatment combinations have been tried the most successful have been aluminum housings with either chrome by the Doehler-Jarvis transplant process, Elnisil (or tungsten carbide). Toyo Kogyo and NSU are believed to be using equipment capable of grinding four to five housings per hour (2 to 2½ engines/hr). Recent reports indicate this may have doubled using diamond grinding wheels. Several U.S. machine tool builders have recently introduced proto-type grinders capable of finishing 20–25 housings per hour (10–12 engines/hr).

Typically, piston engines are produced at 100 or more/hr. It seems likely that another generation of machine tools will be required before high volume production would be economically practical. Even if a cast iron housing could be used without treatment and produced at substantially higher rate, there is doubt whether the Wankel could be produced competitively. So far, cast iron does not look feasible.

IX. CAPITAL INVESTMENT

Closely related to cost are capital investment requirements. The U.S. auto industry and its suppliers are estimated to have invested, at replacement cost, over $50 billion in machinery and equipment (not including plant and land). At least 15 to 20%, or $8–10 billion, is estimated to be in the engine production area. The auto manufacturer's greatest annual investment in machinery and equipment has been about $2 billion. Only a portion of these investments, of course, are in machine tools.

The machine tool industry has an annual capacity of about $2 billion but probably not more than 20–25% can be devoted to the auto industry. Ralph Cross, president of the Cross Co., recently told the Environmental Protection Agency that a changeover to a completely new engine would take 12.8 years, based on present capacity of the transfer (automated manufacturing) machine industry. This could probably be improved upon resulting in a 10 year conversion if warranted. There may be other limiting factors. The lead time to equip the industry with trochoid grinders (even for slow rate grinding) is apparently not one of them.

X. OTHER COMMERCIALIZATION CONSIDERATIONS

Further insight into the possible rate of commercialization may be gained from a look at history of other major new automotive innovations. Figure 12 shows the history of automatic transmissions, disc brakes and air conditioning. The Automatic Transmission took 20, Air Conditioning—17, and Disc Brakes—9 years from successful introduction to a 50% market penetration. All had been marketed unsuccessfully in the U.S. many years earlier.

Disc brakes, for example, were used in production on Chrysler cars as early as 1950. They also had been very widely used in Europe. In addition, they reportedly cost less to produce in high volume than drum brakes—a strong incentive for rapid change.

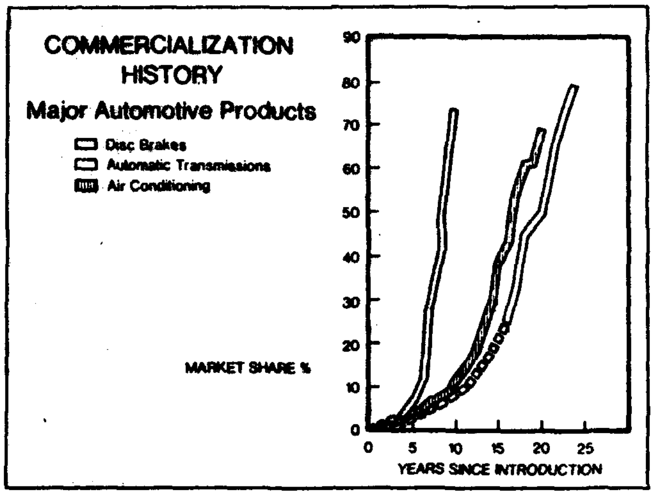


FIGURE 12

Power steering and power brakes took 14 and 17 years respectively to reach 50% market penetration. These are examples of the most successful products. Many lesser successes have not reached 10% and some have approached 10% only after 15 to 25 years.

Many others didn't make it at all—air ride lasted less than two years despite nearly a 3% initial penetration. Fuel injection lasted nine years but had a maximum penetration of less than a tenth of one percent.

Probably the best analogy that can be made is with the change to modern short stroke overhead valve engines (Figure 13). This first shows how the engine market mix has changed since the mid-30's. Superimposed (whiskered area) is a curve showing the transition to the modern engine. This change started in 1948 and was not complete until 1966—18 years later—evolutionary, not revolutionary. In 1948 the industry was due for a change: the last previous significant new engine was introduced 17 years earlier and some engines were approaching 30 years of age. Production tooling was largely obsolete and worn out. Further-

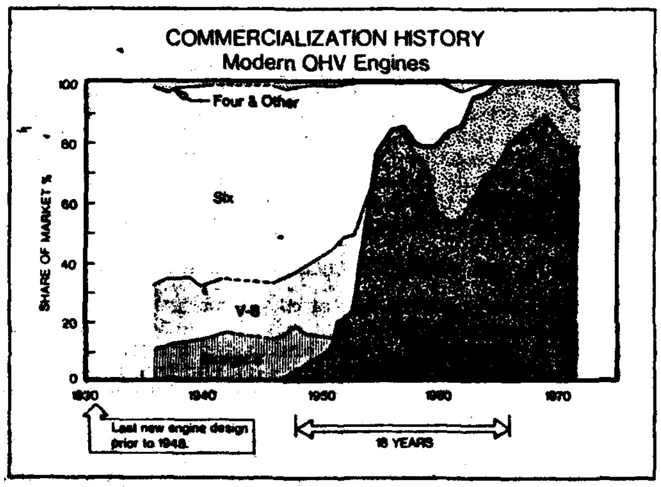


FIGURE 13

more, substantial R&D had taken place on engines and considerably higher octane fuels had become available, both largel in response to artime aircraft needs.

The steep increase in the mid-50's of both modern engines and eight cylinder engines seems to parallel the horsepower or race. Pent-up demand and consumer savings resulting from two wars helped fuel this growth. Had a long term smooth growth curve or V-8 engines taken place, the transition curve would probably have been a typical smooth S curve with the mid-point about 1955. This early growth represents the demonstrated capacity of the industry for major substantial engine change and tends to suggest this conversion to modern OHV engines could probably have been completed in ten to twelve years.

Today the situation is quite different—Ford has a new engine plant just now going on stream to produce the Pinto engine in Lima, Ohio. Ford is also building a new engine plant in Brazil. Two other engines are less than three years old and almost all engines in production have been introduced or retooled within the past decade. In addition, there is a much wider range and greater number of both engine and car models in production. A complete transition could therefore take longer today.

The heavy duty engine producers also have a number of relatively new engines in production or under development for near term introduction, and new plants are under construction to produce diesel and heavy duty gasoline engines.

If indeed substantial cost savings are achieved—more than 15% (and some project up to 30 or 40%)—then there would be incentive to obsolete unamortized tooling, make these large investments, and move rather quickly to the Wankel. With today's demands for corporate social responsibility, the major auto companies could only move rapidly to the Wankel if its serious fuel consumption penalty were substantially reduced. The limiting factor then would likely be the machine tool industry.

On the other hand, if there is little or no cost saving, commercialization will be at a rather slow pace, and at a cost penalty, will be quite limited 55,000 Mazdas at a $600 premium is one thing. There may even be a market of as many as 500,000 U.S. built sporty novelty cars at a few hundred dollars premium—but certainly not a market for 10 million.

XI. MARKET SHARE PROJECTIONS

Passenger Car

Taking all the previously discussed factors into account and applying both optimistic and pessimistic assumptions (within a reasonable range) yields the projected range of probable market share for Wankels shown shaded in Figure 14. The maximum probable is about 13% by 1980 and 28% by 1985. The minimum probable rises to 3% in the late 1970's, gradually fading away in the mid-1980's. The maximum possible curve is based on the assumptions of greatly in-

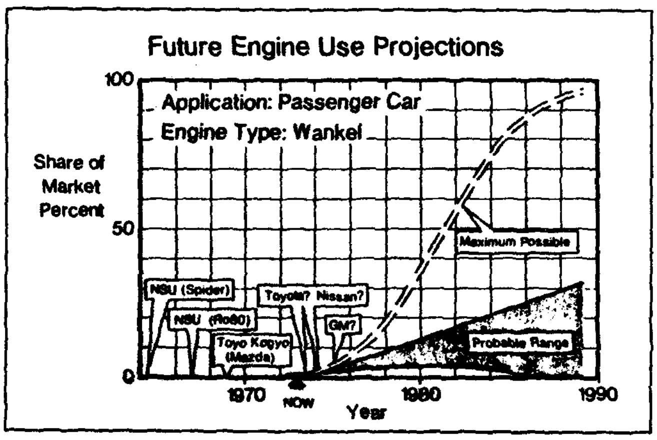


FIGURE 14

creased R&D, major manufacturing developments and the capacity of both the machine tool and auto industries to finance and produce the necessary produc-

tion equipment. In addition, some major incentive for this rapid change which is not now apparent would be required.

Other new engine types are in the picture and must be considered. How long will there be to amortize the investment before it is obsoleted by one of the other advanced powerplants. Figure 15 shows what might happen with the turbine should sufficient progress be made. The Stirling engine could materialize in about this same time frame and would have strong incentive to be commercialized at a rapid rate. Note that the 50% point on the maximum possible curve occurs only six years after the same point for Wankel. This is about half of the usual amortization period for investments of this type.

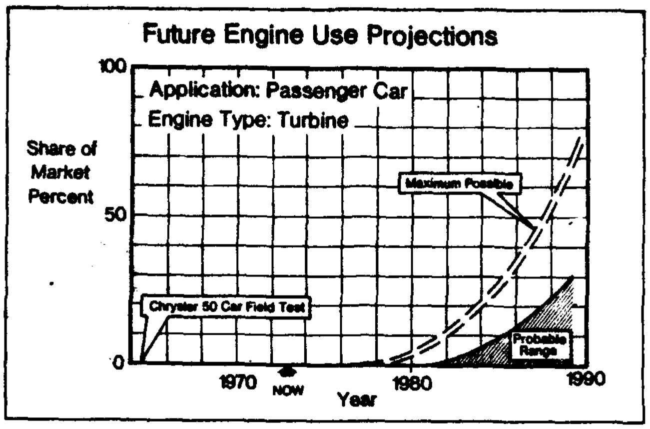


FIGURE 15

The stratified charge engine of course could come much sooner. Although this engine would ordinarily represent a relatively great change—new cylinder heads would probably be required—compared to the Wankel, it is almost insignificant. If larger cars using the Honda stratified charge concept can meet emission standards, and Honda has very recently indicated they can, there would be strong incentive to move to it rapidly.

Figure 16 is a composite of Figures 14 and 15 showing that the great majority of the market will still be for reciprocating piston engines. Also shown are esti-

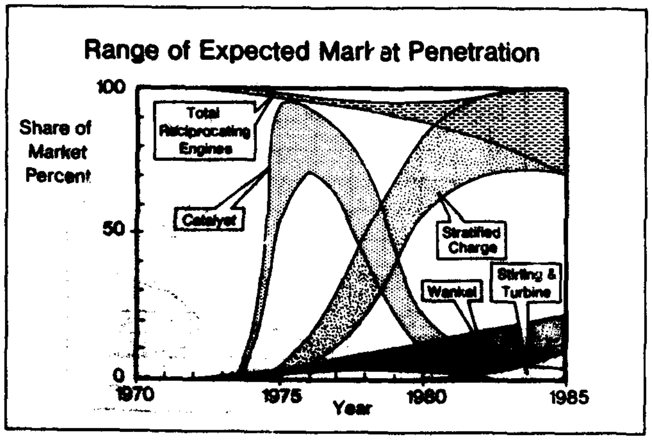


FIGURE 16

mates of the shorter term picture. This graph was prepared before the EPA's granting of a one-year extension on the 1975 standard and creation of interim

standards. It now appears the number of catalyst controlled engines will be substantially lower than shown in 1975. The picture for 1976 and beyond is still very unsettled.

Heavy Duty

Projections for the turbine engine's penetration of the heavy duty market are shown in Figure 17. Ford recently announced they were closing down their pilot

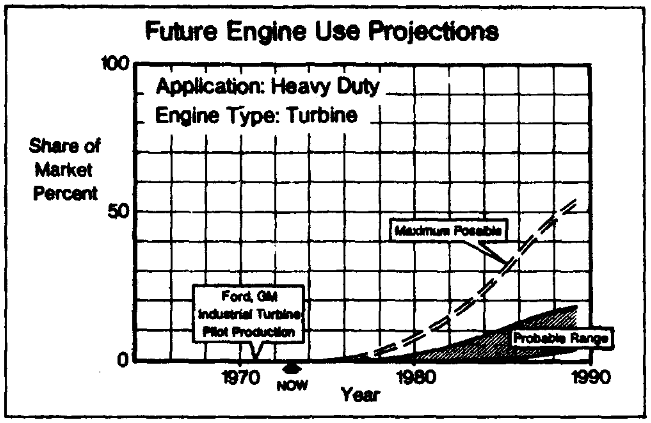


FIGURE 17

production line after building 200 engines to await an improved new design late in the 1970's.

The Stirling engine could not be introduced before the early 1980's and would likely not exceed the upper limit of the probable turbine curve at least until the very late 1980's.

The Wankel, if it comes, will be later and slower. Heavy Duty engine manufacturers are more cautious and move slower than passenger car manufacturers. (Most have new diesel engines under development and some new plants under construction to produce diesels.)

Small Engines

Cost will prevent the Wankel from competing effectively against single cylinder engines except in very limited premium markets—less than a 5% penetration would be expected. The Wankel looks much better compared with multi-cylinder engines used in recreational vehicles (Figure 18). Recreational vehicles include

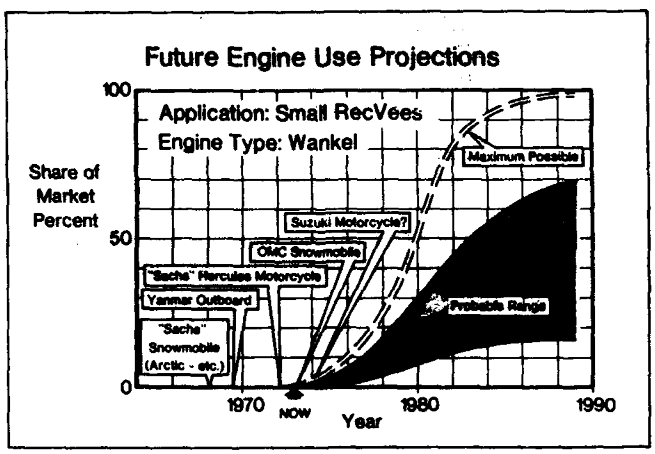


FIGURE 18

snowmobiles, motorcycles, ATVs, outboard motors, etc. The Wankel could replace more than half of these piston engines by the mid-eighties in this application. Despite the greater optimism, there is also greater uncertainty reflected in a wider band in this application area.

Geographic Consideration

These projections generally represent both the domestic and worldwide picture. In the case of the Wankel, Japan will move faster and Europe slower. Europe is ahead on the Stirling with Japan last. The U.S. is ahead on passenger car turbines. The U.S. is also ahead on heavy duty turbines with Europe next and Japan last. Japan is ahead on stratified charge engines and Europe apparently last.

XII. SUMMARY AND CONCLUSIONS

Reciprocating piston engines will remain dominant well into the 1980's. The Wankel engine will receive increased use in passenger cars, possibly approaching a 25% penetration by the mid-1980's, but probably much less.

Wankels will be more significant for small engines, especially compared with multi-cylinder engines for recreational vehicles, perhaps reaching 50% of this market segment, but they will not significantly penetrate the small single cylinder engine market.

Wankels will not be significant in heavy-duty engine applications. Turbine engines have greater long range potential in both cars and heavy duty applications and the Stirling engine probably even greater potential.

In the near term, the stratified charge engine looks potentially very attractive offering required low emission performance without costly hang-on controls and representing relatively minor tooling changes.

Vehicle and engine manufacturers continue to approach change with caution and will follow conservative introduction and commercialization strategies. Economics will continue to be the dominant influencing factor, but social requirements, especiallly fuel consumption, will become more significant in influencing change to different engines.

The overall conclusion, therefore, is that there still is considerable uncertainty as to the choice and rate of commercialization of specific engines, but no revolutions are likely in the near future.

Mr. RICHARDSON. I would like to go through some slides from this report. This lists the more significant engine selection parameters (slide 1).

I believe they are all self-explanatory, with the possible exception of "flexibility". And by that we mean performance flexibility or torque speed characteristics which affect vehicle driveability and transmission requirements.

The parameters on the right are relatively new ones and on the left are the traditional ones. You will note that the two on the right have been labeled "social requirements." Fuel consumption has also been labelled "social requirement" because of the energy crisis.

The real world is even more complicated and includes many detailed requirements too numerous to list on a slide.

Mr. BROWN. I don't notice that you list safety. I guess that wouldn't be an engine parameter.

Mr. RICHARDSON. It conceivably could be, if you were having problems. But this tends to be relative to what we know and have experienced.

Mr. BROWN. A number of witnesses earlier have brought up safety factors, but I guess that applies more to the vehicle itself.

Mr. RICHARDSON. Right.

Engine Selection Parameters

TRADITIONAL	NEW
Cost	Emissions *
Durability - Life	Noise *
Weight	
Size	
Smoothness	
Flexibility	
Maintenance	
Fuel Consumption *	

* Social Requirements

SLIDE 1

Relative Importance of Social Requirements

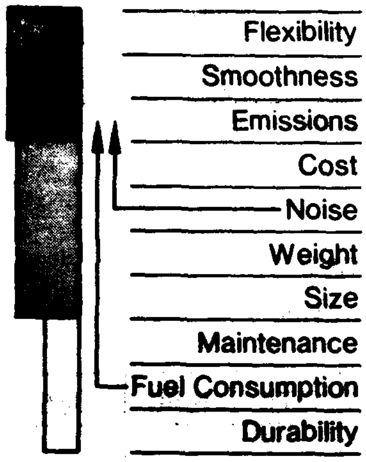
	Aug 72	Feb 73	Mar 74	1975	1980	1985
Emissions	7	7	6	6	6	6
Noise	3	3	3	3	4	4
Energy Resources	1	3	7	10	7	6

SLIDE 2

This next slide (slide 2) considers the relative importance of the three social requirements shown. We have done it on a zero to 10 scale which is obviously a very subjective approach. But I believe it does provide some helpful perspective. It shows how these social requirements change with time. This chart was prepared a long time ago before the recent Mideast crisis, with the exception of the March 1974 column. It shows only a slight lessening in the absolute importance of emissions, some increase in the importance of noise and a very great increase in the importance of fuel consumption, becoming half again as important as emissions before the end of this decade.

Relative Importance of Selection Parameter

Passenger Cars — Compared with 4-Cycle Spark Ignition Piston Engine



SLIDE 3

This slide (slide 3) shows the relative importance of all 10 selection parameters for passenger car applications. They fall in the order shown, with flexibility, smoothness, and emissions leading the list, and maintenance, fuel consumption, and durability on the bottom.

This ranking is for early 1973 values. The arrows on the left show both noise and fuel consumption rising to expected 1980 positions, and perhaps sooner.

This ranking is related to the characteristics of today's piston engine.

Too often well-intentioned effort focuses only on one or a few of these parameters. The result is an engine which may show up well in the prime parameter under consideration but is unacceptable with regard to other required parameters. About 7 years ago much interest arose in the steam or Rankine engine as a readily available, satisfactory alternate having low emissions. At least that was the conclusion of the Commerce Department panel.

So far considerable expense and effort have confirmed the low emission potential but has shown the engine wanting in other characteristics, notably fuel consumption. This example shows how a leading contender becomes unattractive or unsatisfactory when considering only two parameters.

Obviously, consideration of 10 or more parameters greatly increases the complexity of the problem. The auto companies must make and market a product which will find ready acceptance in the marketplace. Failure to do so would result in relatively quick business failure of even the strongest auto company.

No Government agency or any company outside the auto industry, no matter how noble their intent or competent their researchers, has this marketplace discipline working to force practical compromise and an optimum balance of competing requirements.

We therefore believe the auto industry through the discipline of the marketplace and the efficiency incentive resulting from the profit motive in our free enterprise system can better and more quickly place proper weighting on all of these many, often changing, parameters involved in the selection of automotive engines and therefore respond quicker and more economically with the desired product. We further believe that development of automotive propulsion systems—and I mean development and not research—conducted outside the auto industry is wasteful of technological resources because of a lack of immediacy to the problems and discipline of the marketplace.

The Federal Government has been supporting development of the steam engine through the EPA's AAPSD program for a number of years. This effort has produced much interesting data, some laboratory hardware but as yet, no operating steam cars.

During the same period of time, several private developers have produced a number of steam cars, although none could be considered acceptable or competitive to the internal combustion engine.

Wherever test data is available, it has indicated the relatively poor fuel economy of steam cars—fuel consumption three to five times what it should be. Despite this poor fuel economy and EPA's expansion of their role to consider this parameter, steam development programs are continuing under EPA funding.

While this program was initially supportable on the basis of low-emission potential alone, the recognition of an impending energy shortage 2 or more years ago and the demonstrated shortage of the past few months should have been more than adequate reason to redirect this effort to work on high-efficiency, low-emission engines.

While there are some, and I have been among them, who argue that the steam engine has the potential of equaling or exceeding the efficiency of a low-emission internal combustion engine, there are, however, other engines which have both low emissions and much higher efficiency potential and appear to be equal to or better than the steam engine in all parameters.

The marketplace discipline of industry long ago shifted the resources applied to the steam engine to more potentially fruitful projects. It appears that Government-sponsored development cannot so effectively respond to a changing marketplace or changing needs. It is, therefore, questionable whether an expanded Federal automobile

engine development role would be significantly more beneficial or would only compound the misdirected effort.

Applying development resources to organizations without the ability to exploit the development is inefficient, wasteful, and results in needless duplication. It introduces or increases technology transfer problems and consequently increases lead times.

I believe a fuller understanding of automobile product development leadtimes could be helpful. I have a series of charts which illustrate leadtimes and how Government input impacts on the product. These charts have been synthesized from various auto industry sources and are consistent with our experience as a supplier.

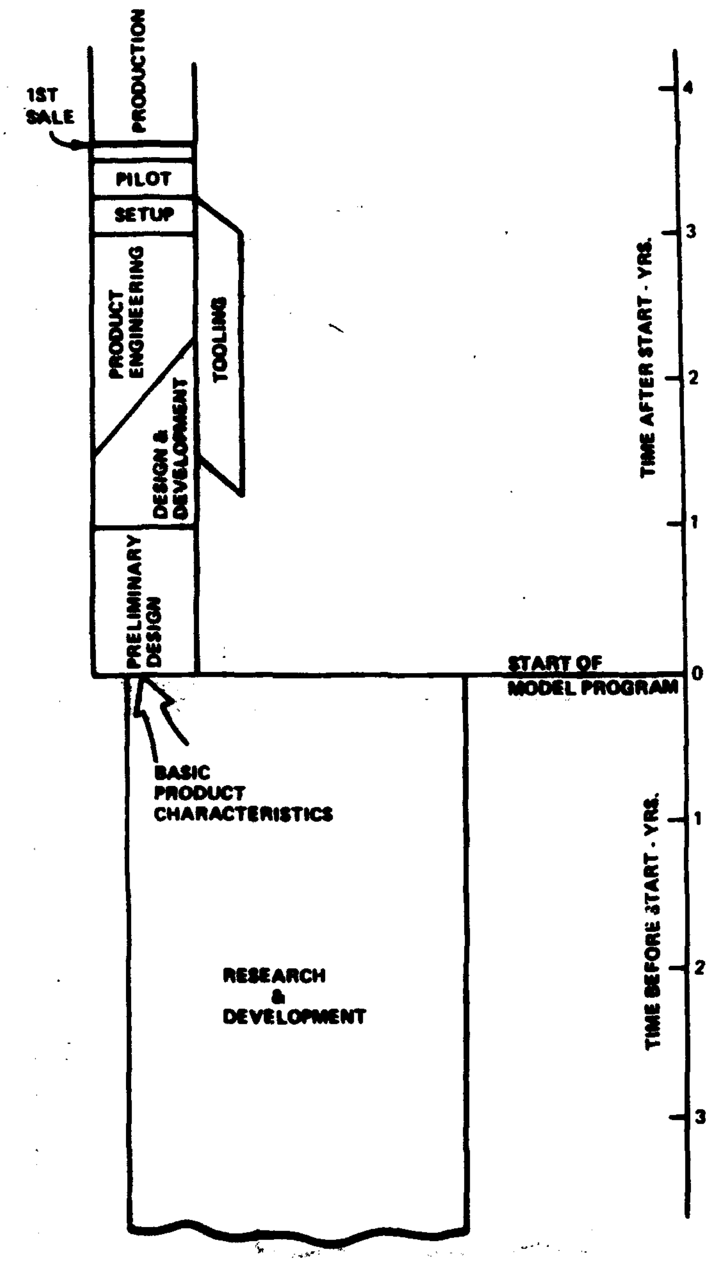
I must apologize for the quality of them. I think this illustrates the problem I am talking about. Our artist who would normally do them has been sick the past week. We sent them outside, and there were a number of goofs. They are so bad you can't read them. There is a printed copy attached to the statement.

Mr. BROWN. I am looking at the printed copy.

Mr. RICHARDSON. This slide (slide 4) shows a simple version—the leadtime for an all-new model passenger car for one car line utilizing existing technology. Time zero, or the horizontal line, is taken from the start of the new model program. The leadtime to the first sale is 3½ years. Below the horizontal line is shown the continuing research and development activity which has led to the technology available for use in this and previous models.

Let us now add on the right the leadtime for a new conventional engine (slide 5); that is, an internal combustion engine based on existing technology but larger or smaller in size and with minor design refinements requiring new tooling. It shows the engine completed just in time for installation in the new car.

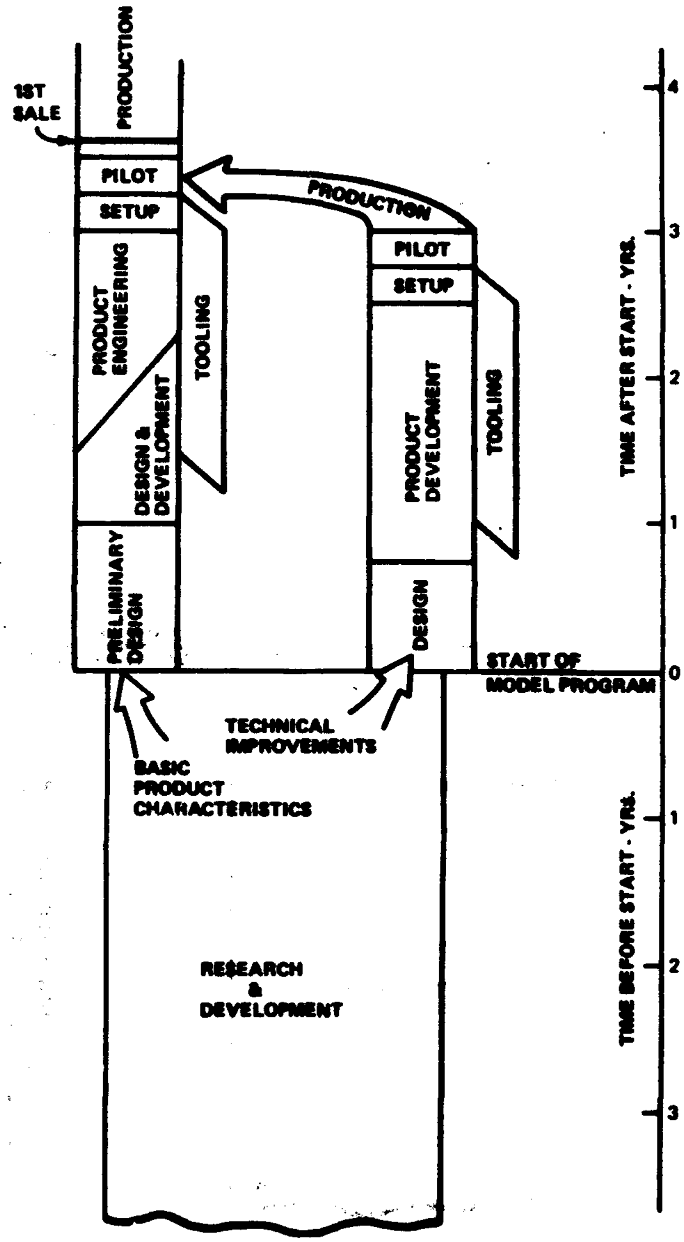
LEADTIME ANALYSIS
19XX MODEL PASS CAR



SLIDE 4

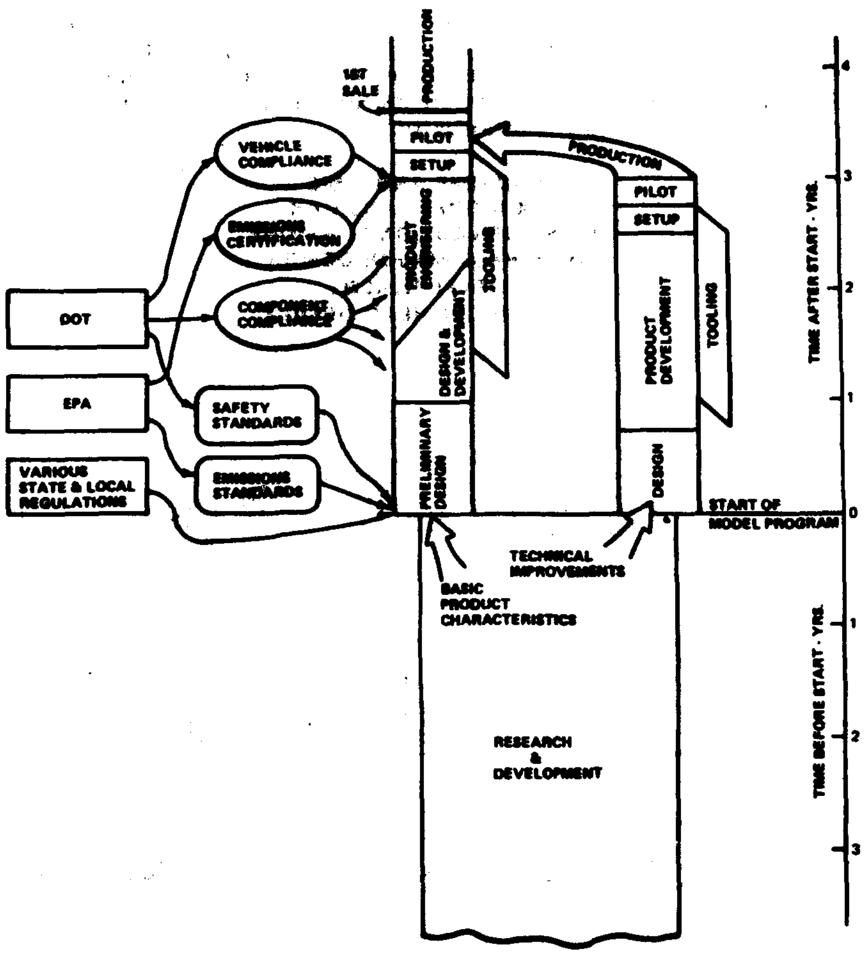
36-993 O - 74 - 27

LEADTIME ANALYSIS 19XX MODEL PASS CAR WITH NEW CONVENTIONAL ENGINE



SLIDE 5

GOVERNMENT INTERFACE
WITH PRODUCT PLANNING



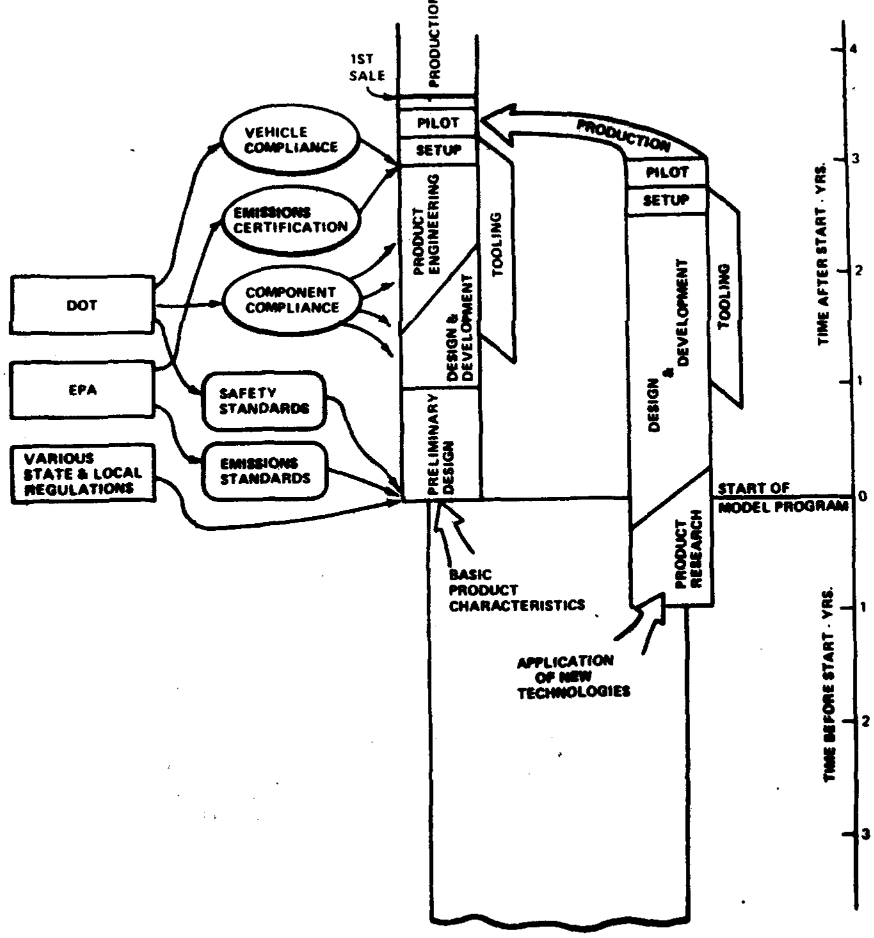
SLIDE 6

Now let us add Government regulatory activities on the left which impact on the product (slide 6). We have tried to show their approximate timing in the new model development cycle.

Not shown, but of perhaps more concern to the subcommittee, are impacts of proposed or actual safety and emission standards several years back in the R. & D. effort. The importance of this will become more apparent in the following charts.

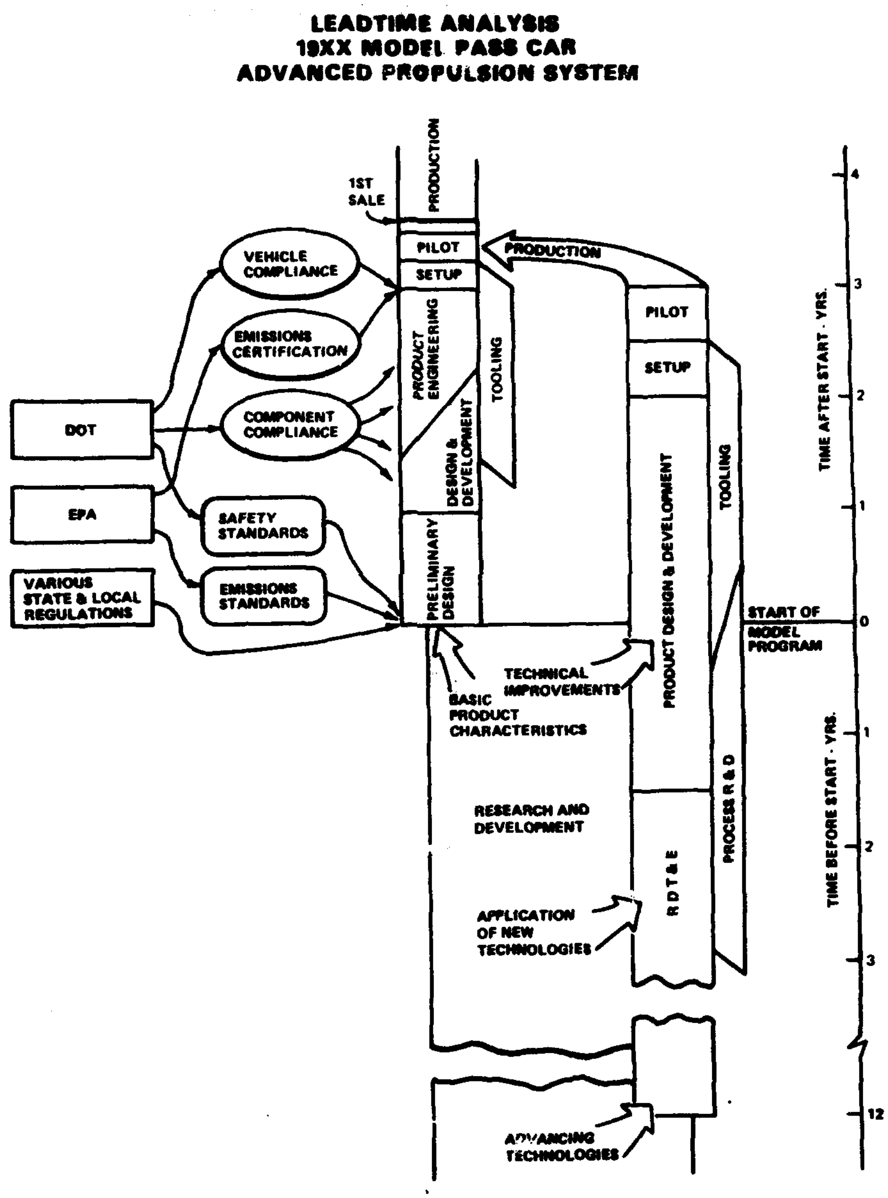
This next slide (slide 7) shows the addition of approximately 1 year to the cycle for incorporation of a new conventional engine with a major modification such as a new cylinder head for a stratified charge engine. These times shown assume the technical feasibility first being demonstrated in a research project at the auto company. It should be kept in mind that these charts are based on one car line or engine line. If the industry tried to convert all its cars at the same time, tooling leadtimes would increase substantially.

LEADTIME ANALYSIS
19XX MODEL PASS CAR
WITH CONVENTIONAL ENGINE
REQUIRING MAJOR DESIGN
& DEVELOPMENT
e.g. NEW CYL HEAD DESIGN



SLIDE 7

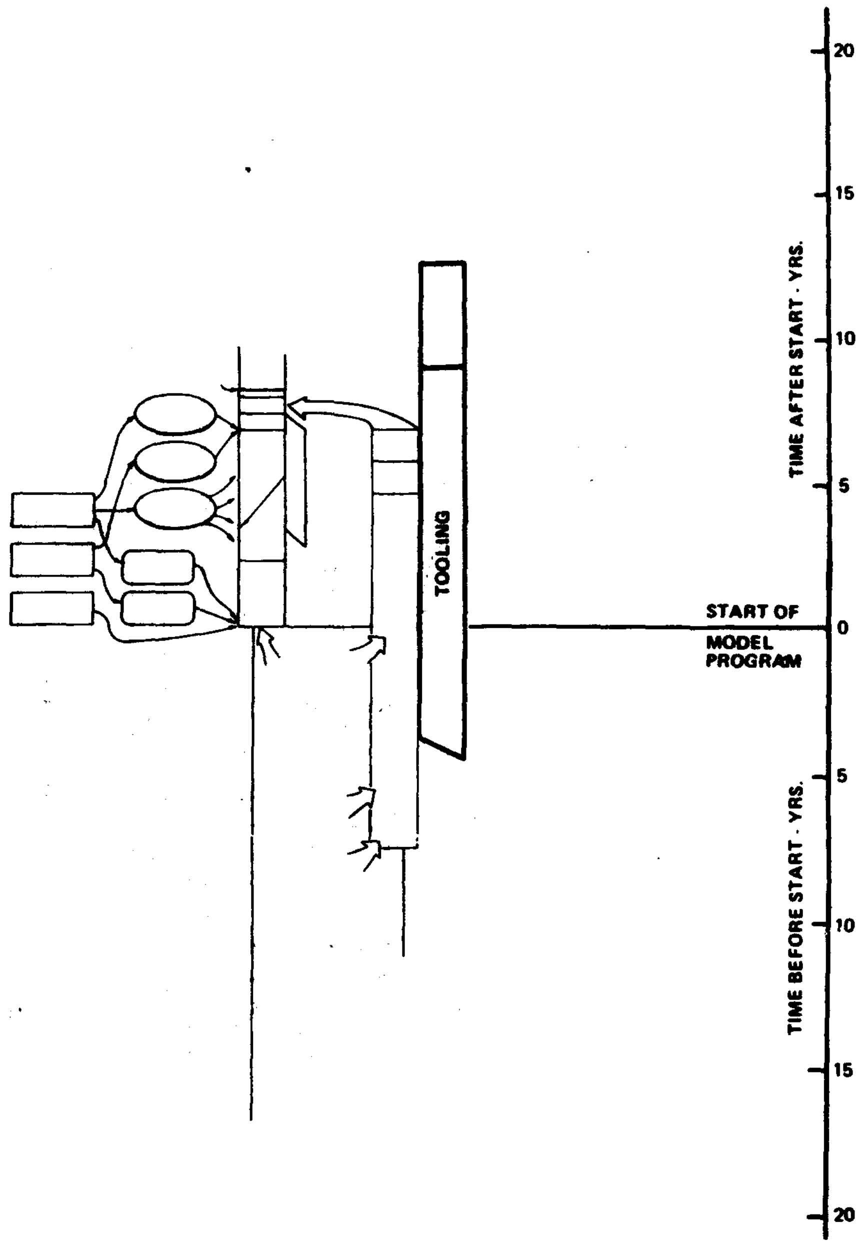
Our next slide (slide 8) shows a very great increase in leadtime up to about 12 years increase or a total of 15½ years to introduce a totally new engine such as a turbine engine or a Stirling engine based upon a new technology and new manufacturing processes and techniques.



SLIDE 8

Let us look at the same chart—slide 9—but shrunk so that the additional 10 to 13 years required to completely convert the whole industry

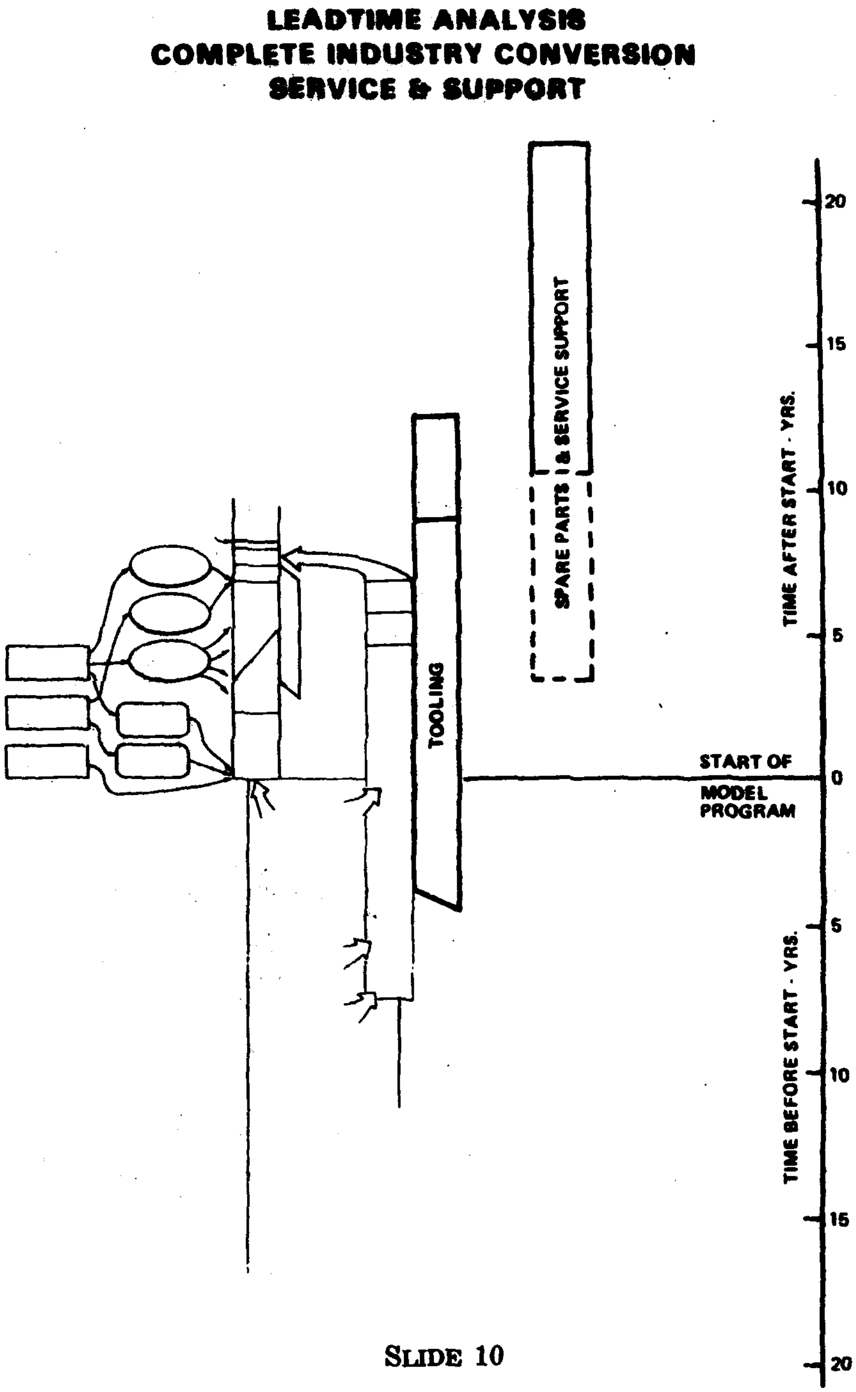
LEADTIME ANALYSIS
COMPLETE INDUSTRY CONVERSION



SLIDE 9

will fit on the chart. Again, our outside artist goofed, and the two scales are not comparable, but I think you can get the idea.

The leadtime from start of R. & D. on a new engine to complete conversion of new production is about 25 years minimum, if successful—slide 10.



SLIDE 10

Finally, we show the additional minimum time during which a significant quantity of these engines would be in service if production should cease as soon as conversion of production equipment had been completed—a total span of about 35 years or longer.

Obviously, from an economic standpoint, this time would be much longer. The chart does, however, indicate that decisions made by one generation are likely to have a significant impact on the following generation.

At this point I would like to call the subcommittee's attention to a paper, "1970's Development of 21st Century Mobile-Dispersed Power," presented last August by our director of research, Dr. Lamont Eltinge, to the Society of Automotive Engineers. You have a copy and I would like to have it in the record.

Mr. Brown. Without objection.

1970's Development of 21st Century Mobile-Dispersed Power—A Challenge Requiring New Technical Solutions and Systems-Management

(By Lamont Eltinge, Director of Research Eaton Corporation, Southfield, Michigan 48076)

Abstract

A mobile and dispersed power system is necessary for an advanced technological-industrial human society. Today's is based on petroleum and discharges waste products and heat. It is growing exponentially. Energy resource *commitment* has already intersected "ultimate" low-cost petroleum supplies in the U.S. and will do so for the world before 2000 A.D.; this portends major changes and cost increases.

The 21st Century system for mobile-dispersed power will reflect the energy source selected to replace petroleum—e.g., coal, solar insolation or uranium. It will incorporate a fuel intermediate such as methanol, ammonia or hydrogen, and a suitably matched "engine".

The complete change will require 25+ years because of the magnitude, fragmentation, structural gaps, complexity and variety of the mobile-dispersed power system. Consequently, *substantial, sustained, interacting and coordinated planning*, research and advanced development must be started now and completed during the 1970's. A "system dynamics" model of the resource-fuel-engine-use complex, and a "mixed-economy" Energy and Ecology Cybernetics Corporation should be integral parts of the effective management of the unprecedented development of society's 21st Century mobile-dispersed power system.

Introduction

Harnessing of mechanical energy has been and will continue to be crucial to mankind's progress. To date, we have avoided Malthus' dismal prophecy—regression to the starvation level as population increases—through ever more effective use of intelligence, industrialization, and mechanical energy. Without a substitute for his own muscle power, man can devote little of his time and energy to higher pursuits. There has been a general proportionality between energy consumption and organized economic activity, as shown in Figures 1 and 2; and both have been growing exponentially.

Calls on the same finite and irreplaceable fuel and environmental resources cannot expand exponentially forever. An impending change is foreshadowed by the fuel shortages in the U.S. which have impacted moderately upon comfort, convenience, activity, and costs. (1–3)* The smog in Los Angeles and Tokyo and the CO levels in Chicago and Europe evidence environmental impact. These are serious to the individuals affected and subject to various interpretations. (4–10) But, more important to mankind as a whole, they are *early warning signals* of:

(1) Intersections of demand and supply, and of industrialization and the environment;

(2) Need for effective management of a *major change* in our technical-industrial society.

The "energy crisis" has been and is being extensively documented, discussed and publicized (11–31). But, most attention has been directed to the overall energy problem and electrical power. *Little has been addressed to mobile and dispersed power* even though it is by far the most dependent on the scarcest fuel resource—petroleum.

Mobile and dispersed engines provide one-half of man's mechanical energy and consume one-third of his fuel. The present complex, varied and changing system of engines, fuels and infrastructure has done quite a job. It is embodied in tractors, timbering and mining equipment, trains, barges, ships, trucks and automobiles, motorcycles, snowmobiles, chain saws, power mowers, outboard motors, etc. Through use of such mobile and dispersed non-animal power, less than ten percent of the U.S. population provides the food, fiber and fuel, and extracts natural resources on which our advanced technological society provides the highest standard of living in history. With transport, which is based on mobile-dispersed power, we tap remote resources, practice extensive specialization and obtain the associated high productivity and experience enrichment from recreation, travel and varied social contact. We may not be applying our energy and environment resources to mobile-dispersed power with the greatest wisdom and efficiency; but mankind would be worse off without it.

By the end of the 20th Century—the century of abundant and cheap crude oil—the cost and availability of petroleum will have changed so much that some other primary energy source for mobile-dispersed power will probably be either required or much more attractive. The system can continue in a non-optimum form for decades. But with the U.S. alone likely to spend $100 billion per year for fuels for mobile and dispersed power in 2000 A.D., even 1% non-optimal operation imposes substantial loss. Complete change-over in the fuel-consuming equipment population and the plants for processing energy resources into fuels takes longer than a quarter of a century, and the earliest parts of a new development are the lowest expenditure-rate phases. Therefore, good stewardship requires that current advanced-development ngines be designed for 2000+ A.D. energy resources and fuels, and that the *present* generation identify and conduct advanced development ... the 2000 A.D. system. Lack of consideration of a different fuel situation in 2000 A.D. in the advanced developments of '73–'76 in effect constitutes a decision that petroleum-based fuels will continue to predominate as best *after* the turn of the century. Although there are a few exceptions (62), this is currently the general case and a risky assumption.

A change from petroleum and gasoline or diesel engines would be of unprecedented magnitude and complexity: it would dwarf railroad dieselization and the shift from horses and wagons to automobiles and trucks. The U.S. is a natural site for definition and solution of the problem because it predominates in the use of such power, has world leadership responsibilities, is concerned about the international monetary and power implications, and has the industrial/technical capability; but also will have the greatest crude oil deficit. The major suppliers for a 2000+ A.D. energy resource-fuel-engine system must interact on this challenge intensely and imaginatively to come up with a good answer. They have not done so to date.

The initial steps in progress toward meeting the energy/environment requirements for mobile-dispersed power after 2000 A.D. as a major and crucial part of the total energy picture, should be based upon:

(1) Recognition and understanding of *the problem*—its origins and the likely time scales and magnitude of responses;

(2) Summarization and evaluation of the *possible* technical responses; and

(3) Consideration of the entire resource-fuel-engine-use-infrastructure *system* and a suitable way to *manage* the unprecedentedly rapid and large changes.

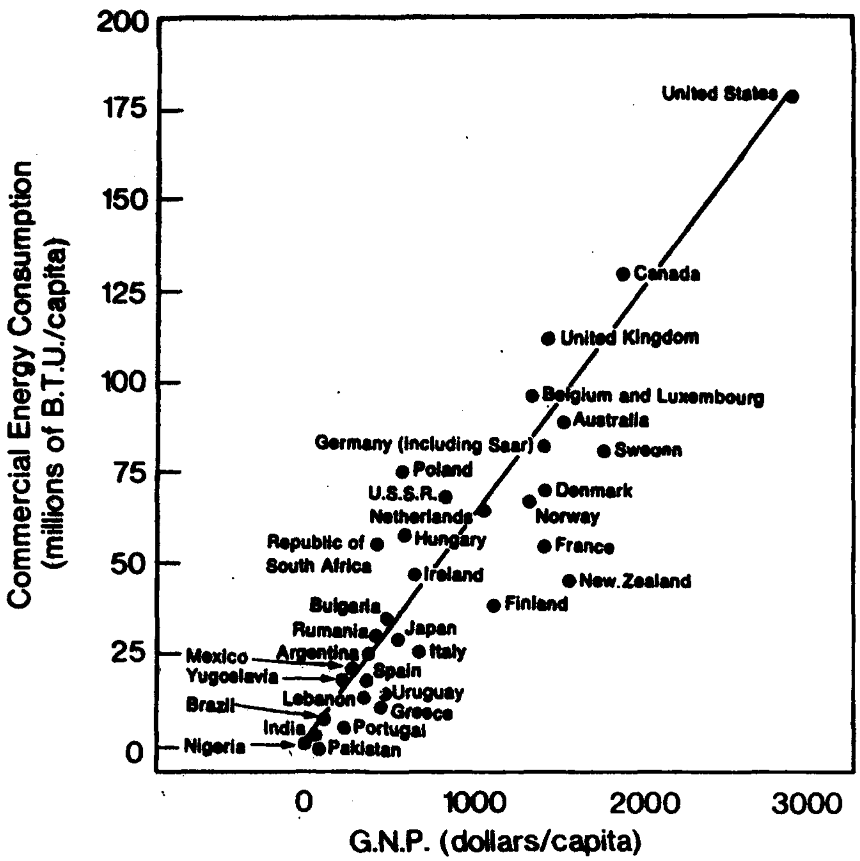


FIGURE 1.—Relation between Energy and GNP, 1961. (Source Ref. 57.)

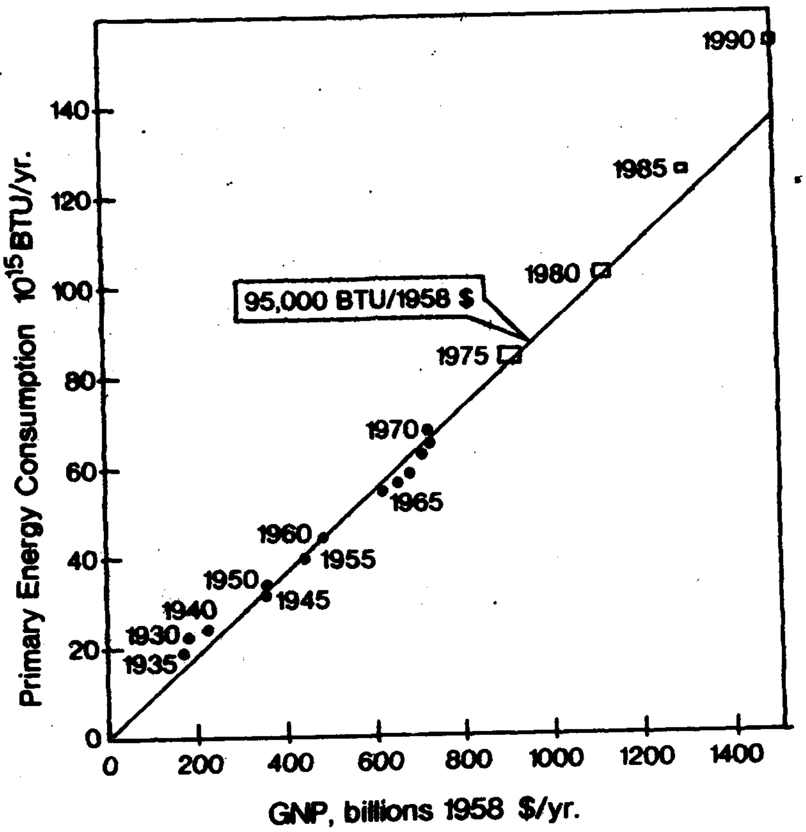


FIGURE 2.—Energy Consumption and GNP in the U.S. (Source Ref. 77.)

PROBLEM ORIGINS

The need for defining the 2000 A.D. resource-fuel-engine system, selecting the concepts, developing the hardware, and evolving the management system during the mid 1970's results from the interaction of:

(1) Exponential *growth* in use of mobile-dispersed power

(2) The finite and approaching limit on *crude oil* resources and the rising cost of finding and producing them

(3) The complexity and variety of the producer-user system and its separated structure, and

(4) The *long* delay between problem recogniiton and full implementation of any new technological system of such complexity, variety and magnitude.

Demand for use of fuel has been growing exponentially at 3% to 5% per year (30, 32, 34, 35, 40, 55, 57, 64–70) as shown in Figures 3 and 4 and Table I, and is projected to continue to grow exponentially. As a consequence of such exponential growth:

(1) *Use rate* and *accumulated usage double* every fifteen to twenty-five years.

(2) Half of the fuel that mankind has ever burned has been burned since Sputnik was launched.

(3) Before a baby born today is old enough to drive an automobile, mankind will use roughly as much fuel as has been used from the dawn of industrial history.

If the world's use of energy rose to equal the U.S. *1970 per capita consumption by 2000*, it would increase *10%* a year *even if population did not increase.* Stopping the advance in standards of living and energy consumption would conflict with rising expectations and aspirations for equality and cause social and international conflict. So, a continued growth in demand for energy consumption is to be expected even though rising cost will dampen demand growth.

The underlying constraint on our use of petroleum is the finite amount of fuel resource accessible in the earth's crust. Man has found and tapped the easiest and cheapest sources.

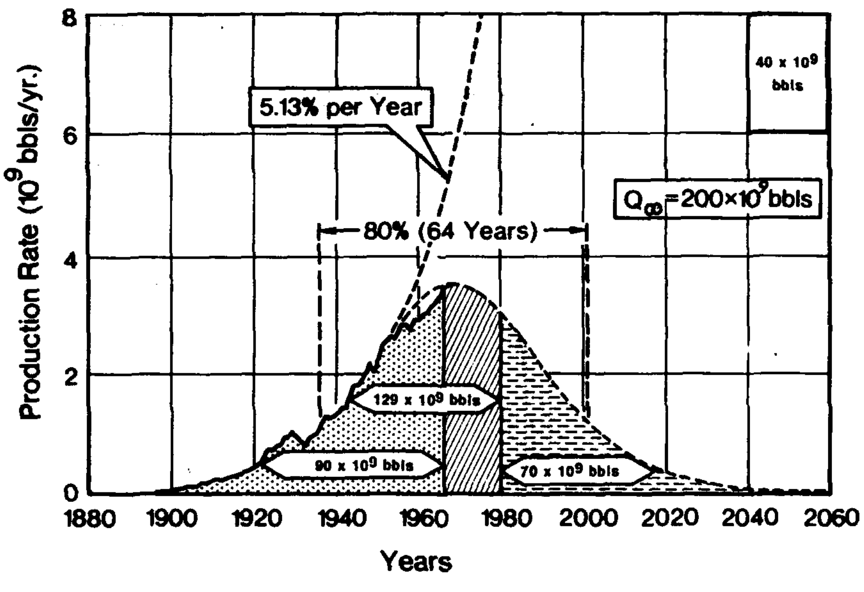


FIGURE 3.—Complete Cycle of Production of Petroleum Liquids in the United States and Adjacent Continental Shelves, Exclusive of Alaska. (Source Ref. 30.)

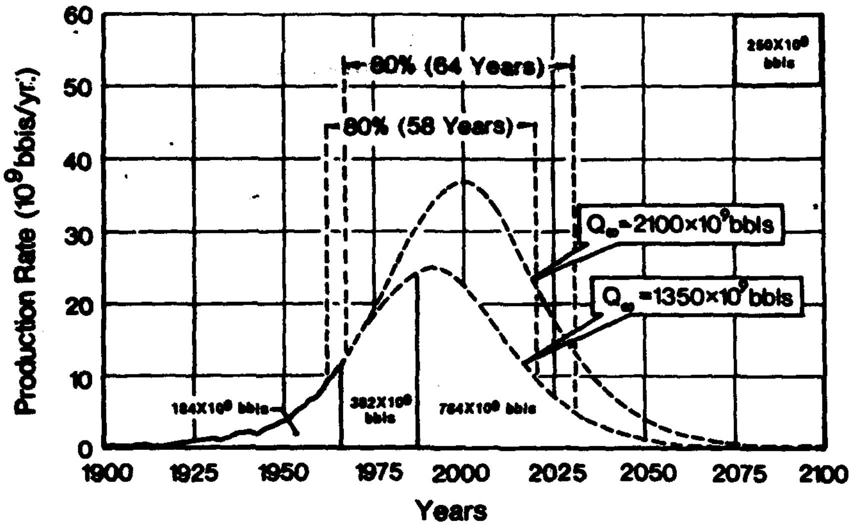


FIGURE 4.—Complete Cycles of World Crude-Oil Production for Two Values of Q. (Source Ref. 30.)

The U.S. has been the greatest user of fuel resources and, therefore, is closer to the ultimate limit than the world as a whole, as shown in Table II. Projections of crude oil production in the United States from the National Academy of Sciences Study "Resources and Man" (30) suggest that the U.S. has already passed the peak and mid-point in production of crude and that the world crude production soon will fall short of demand. Crude finding/recovery can be accelerated by more intense exploration and development, but at substantially increased cost (70)—an expression of the underlying resource-limitation economics that will, in time, force mankind to build its mobile and dispersed power system upon another resource base. This course is being recommended and is likely to be followed to some extent; however, it is only a stopgap. While there is some range in the estimates of ultimate crude oil production, a limit will be seen about the turn of the century and with exponential growth in demand, even doubling of the ultimate recovery would only delay a change two decades.

The engine-fuel-user system is both large and varied. Annual expenditures for fuels and engines are roughly $50 billion or 5% of GNP. In the U.S. alone, automobile manufacturers in '73 make 45 different standard gasoline engines and as many more optional ones, according to "Automotive Industries" (71). Over 400 different gasoline and diesel engines are manufactured for trucks, buses, tractors and industrial equipment. Over 150 different small gasoline engines are manufactured. Fuels for these engines are refined in over 100 refineries. The fuels and engines are distributed through over 500,000 retail outlets, most of them independent businesses. They are used by over 100,000,000 independent entities. The interaction of the many separate companies and industries is limited by law and custom; therefore, development of overall leadership and direction for the entire system is limited.

TABLE IA
ENERGY USE GROWTH RATES

U.S.	**Period**	**Rate %/yr.**	**Comments**	**Reference**
Total	1970-2000	3.2	also 4.35 decreasing to 3.5 and projections to 2250 equilibrium	119
	1970-2000	3.6	scaled from chart	58 pg 258
	1950-1975	5.1		30 Fig. 8.22
	1968-2020	3.0		91
Transport	1960-1970	4.2	automotive gasoline	120
World				
Total	1955-1960	3.4		70
	1960-1965	4.8		70
	1965-1970	5.9		70
	1975-1990	5.5	estimated	70

TABLE IB
ANNUAL USE RATES OF ENERGY AND FUEL

U.S.		**Reference**
Petroleum	5.4 Billion bbl/yr. (1970) - Use	58
	3.1 Billion bbl/yr. (1970) - Production	120
Coal	0.519 Billion tons/yr. (1970)	58
Total	20.2×10^{12}kWh/yr.=7×10^{16}BTU/yr. (1970)	119
	7×10^{16}BTU/yr.	58
	6-7×10^{16}BTU/yr. (1970)	57
World		
Petroleum	14.5 Billion bbl/yr. (1970 Free world)	70
Coal	2 Billion tons/yr. (1970)	70
Total	18×10^{16}BTU/yr. (1970)	70

TABLE IIA
PETROLEUM RESOURCES

		Reference
U.S.	39 Billion bbls *proved reserves*	120
	39 to 89 Billion bbls *proved* reserves	70
	324 Billion bbls *ultimate* production (40% recovery x810 Billion bbls oil-in-place.)	35
	113-*200*-270 Billion bbls est. ultimate recovery	30
	52 Billion bbls identifiable and recoverable	53
	502 Billion bbls recoverable	66
	(+111 Billion bbls recoverable - Alaska)	66
	(+2860 Billion bbls submarginal)	66
	374 Billion bbls (incl. North Slope)	77
World	2,680 Billion bbls ultimate *production*	
	(40% recovery of 6,700 Billion bbls possible, *ultimate oil-in-place)*	
	570-1350-2100 Billion bbls est. ultimate recovery	30
	400 Billion bbls *Reserves* in 1985	70

TABLE IIB
OTHER FUEL RESOURCES

U.S.		Reference
Coal	220 to 4.0 Billion tons proved reserves	69
	778 Billion tons remain in recoverable	77
	200 to 390 Billion tons identified & recoverable resources	66,53
	(+2840 B tons additional *undiscovered* and submarginal)	66
	1486 B tons minable coal and lignite	30 GFig 8.24
Shale	200 B bbls recoverable from Green River formation	58 pg 107
	160-600 B bbls	53
Tar Sands	200 to 300 B bbls recoverable oil	58 pg 107
World		
Coal	7,640 B tons minable coal and lignite	30 Fig 8.24

The current engine-fuel system is highly developed, technologically and structurally, as well as huge and varied. A replacement or change must approach the same level of finesse and size to serve adequately. Such development takes a long time. How long can be projected from experience with *smaller* changes in *conventional* engines—e.g., the shift to OHV engines or low emission engines. The steps of change in the system can be viewed as those shown in Table III.

TABLE III

Engine System Creation

Step	Years
Need or Opportunity Definition & Decision to Develop	1-2
System Concept Creation & Opportunity Communication	2-10
Advanced Development of Prototype Hardware & New Technology	3-12
Product Development, Field Testing & Release of Specific Design & Tooling for Initial Commercial Production	5-8
Market & User Experience and Decision to Convert	2-8
Tooling for Entire System Changeover	8-12
Production of Engines to Change 1/2 the Population	4-7
Total	25-59 yrs.

The total time of 25 years for changeover seems long, but, experience seems to substantiate it. The Wankel is over 25 years old, almost died, is not yet a sure thing and is only at the "initial production" stage. Automotive gas turbines and Stirling engines have even longer pre-introduction histories; they're not yet in commercial production. Addition of the time for each step is an over-simplification; different phases can be overlapped. Iterations of the early steps and additional coordinate steps—e.g., creation of new designs and manufacturing techniques for mass production of complicated and effective components at low cost—take more time. Some acceleration can be effected at greater risk or through parallel efforts. This is most cost-effective in the early phases. It's very risky and expensive, if not impossible, to duplicate the major tooling phases; they must be right.

The resource-to-fuel processing part of the system has similar steps, risks and lead times. Fuel process research and development take as long as engine R & D. It takes 8+ years to design and build *one conventional* refinery; developing a new process involves risks and takes time. There's a finite limit on process equipment construction capacity and the rate at which new processing can be brought on stream. Only the time to change one-half the fuel in the field is appreciably shorter.

Development of a *combined* fuel-engine system will require interaction and, therefore, take longer than development of either a new engine or a new fuel. Extensive interaction and coordination at the early phases is necessary to minimise serious loss of time, effort and resources. All new engines have been developed on conventional fuels, although the gas turbine and Stirling engines have been demonstrated on others; *none have been developed specifically to provide an optimal system with a fuel from an alternate resource.*

The need to start intense development of the 2000+ A.D. system in the mid-1970's is illustrated by some oversimplifications. For this purpose, the delay to effective conversion of production of new engines to a new fuel-engine system may be taken as 20 years; over the subsequent 15 years, the population of engines and use of fuel of the old type may be taken to decrease linearly to zero. Even if additions to the U.S. engine population were non-petroleum consumers starting in '74 (neglecting the delay to substantial introduction), all the ultimate expected future petroleum production in the "lower 48 states" would fail to meet the demand, as shown in Figure 5; some engnies would be fuelless before being scrapped. *All of the engines going into service between now and 1993*, the earliest date of mean-effective changeover to a new fuel-engine system, *must in effect operate on imported or substitute petroleum*; use of imported crude has started to rise sharply. For the world, petroleum will serve a little longer, as shown in Figure 6. Yet, estimated *ultimate* world crude production will be required to fuel engines built before 2000 A.D. And for the world, there's no effective way to import crude from another source. *Thus, advanced development and introduction of a new system is required much earlier than anticipated and should start very soon.*

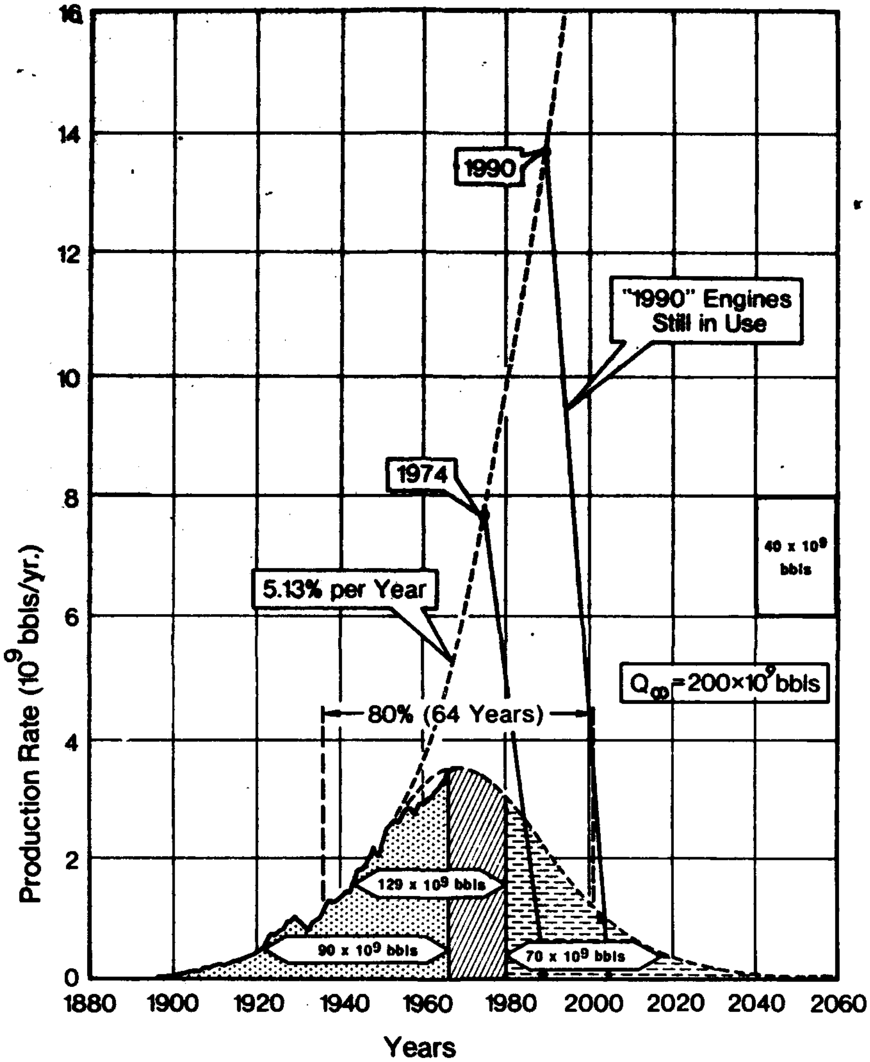


FIGURE 5.—Complete Cycles of Production of Petroleums Liquids in the United States and Adjacent Continental Shelves, Exclusive of Alaska. (Source Ref. 30.)

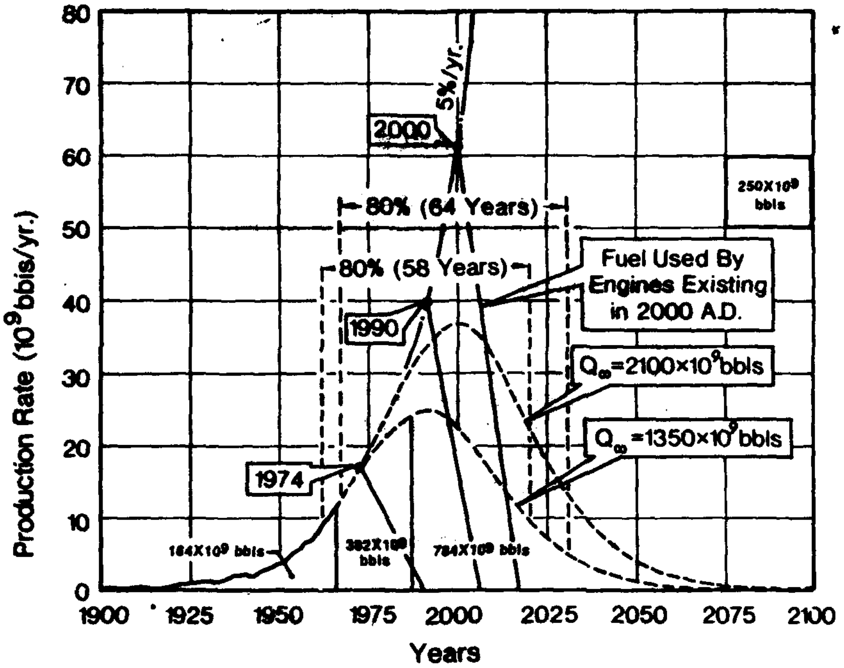


FIGURE 6.—Complete Cycles of World Crude-Oil Production for Two Values of Q. (Source Ref. 30.)

TECHNICAL RESPONSES

Criteria

The criteria for selection of the best possible 2000+ A.D. resource-fuel-engine-use system are:

(1) It does the spectrum of jobs mankind will require of mobile-dispersed powers in 2000 A.D. to 2050 A.D.

(2) It will be suitable for 50 years; it is likely to be amenable to refinement, development and adjustment to changing requirements; it has reasonable overall energy efficiency and won't consume the available low-cost fuel resources and make the system economically unattractive in less than 50 years.

(3) The necessary "commercial" technology and materials can be developed in time.

(4) It is within resource constraints—physical, human and capital.

(5) It has the lowest total cost—i.e., resource and effort requirement—or, conversely, the optimum total value.

(6) It allows a reasonably smooth transition from the petroleum-based gasoline engine system.

(7) It has acceptable environmental impacts and safety; it is not rendered unsuitable by non-obvious side effects on society and the earth.

Timely development of necessary technology both imposes urgency and excludes alternatives. It requires that the underlying science and system concepts must either be in hand or developed in the next several years. It excludes some very intriguing possibilities such as the conversion of heat to energy in apparent violation of the second law (72), exploitation of the forces of magnetism or the use of molecular sieves in engines. While such inquiry should be encouraged and followed with interest, it cannot be regarded as well enough developed to warrant selection as a basis for the 2000+ A.D. mobile and dispersed power system.

Possibilities

The 2000+ A.D. resource-fuel-engine-use system will consist of selected elements from the alternatives outlined in Table IV. For every energy resource, there is a best fuel intermediate and engine combination; so the selection depends on

the total system optimization. Today, and probably in 2000 A.D., fuel cost dominates total cost; for each dollar spent for an engine, three to six dollars are spent to fuel it before it stops operating. Yet the engine *design* determines the tolerable or required fuel characteristics and cannot be changed on a large scale after manufacture.

TABLE IV

Elements of 2000 A.D.+
Mobile-Dispersed Power System

Energy Sources
Oil, Tar, Shale
Coal
Solar Energy
Agricultural or Metropolitan "Wastes"
Other (possibly longer range)
— Nuclear Energy
— Geothermal Energy

Intermediate Transportable Fuel
Gasoline
Distillate
Ammonia — from atomic electricity (74, 75)
Methanol — from CH^4
— from coal
— from sun via plants
Methane — Cryogenic or Compressed
Hydrogen — Cryogenic, Compressed or Hydrides
— from atomic electricity
Powdered Coal
Other

Energy Conversion Devices
Internal Combustion Engines — Present Form with Refinements
Internal Combustion Engine — Substantially Modified Form
Diesel Engine
Regenerative Internal Combustion Engine
Gas Turbine
— Open Cycle
— Closed Cycle
Stirling Engine
Rankine Engine
Fuel Cell Plus Electric Motor
Battery Plus Electric Motor
Other

Results
Shaft Power
Ultimate Use of Applied Power
Environmental Impact

More oil can be found or recovered but at substantially higher prices (34, 35, 70, 76). Liquid hydrocarbons can be obtained from tar sands or shale, but at higher prices and in limited amounts. For extensive amounts the concentrations are relatively low and, therefore, the cost by currently envisioned methods is relatively high.

Coal is the dominant fossil fuel resource, particularly in the U.S. Coal gasification and liquefaction are being developed (77–86). In situ gasification is beting explored and should be promising in terms of both cost and environmental impact (87, 88); as the amount of such processing required is increased, the development effort to create such new technology should be more attractive.

Solar energy can be a direct source of power through photoelectric or thermoelectric phenomenon. An "energy plantation" (89), or secondary use of agricultural and metropolitan "wastes" could make solar insolation the primary energy resource (90–91), but a significant increase in the approximate 1% efficiency with which plants currently fix solar energy is required (91).

Nuclear energy (42, 92) and geothermal energy (93, 94) are sources of heat that can subsequently be used either to generate electricity, which can be used for generating transportable fuel, or through non-electric process made to yield transportable fuel.

A readily handleable, relatively safe, transportable form of energy is required. While other forms are possible, a liquid fits that requirement most clearly. It could be conventional gasoline or distillate; however, another intermediate could better optimize energy efficiency and environmental impact. For instance, methanol has lower flame temperatures and burns leaner than gasoline and might permit more sociable engine operation. It appears particularly attractive in view of some current work on methanol synthesis, estimates of prices on the order of 4¢/gallon and current market prices as low as 12¢/gallon (95–102) Ammonia can be made solely from electrical energy, water and air and does not require a source of carbon. Methane and hydrogen (103, 104) are other possible fuels but have more demanding handling requirements.

Modifications of the internal combustion engine, perhaps with regeneration, operating on a fuel such as methanol could meet requirements for efficiency and socialability. In addition, they could offer the easiest transition from our current system.

Efficient use is important. This can result from improvements in the way the land is plowed, resources are mined, or people and things are located and moved. Car-pooling and mass transit improve energy use and efficiency. Limitations on maximum vehicle speeds and discretionary recreational uses, such as snowmobiling and water skiing, are also possible.

It is likely that 2000 A.D. will see some combination of these responses rather than one. However, one is likely to dominate and current attention should be focused on it.

Schedule of Subsequent Steps

A number of alternative systems consisting of combinations of elements are possible responses. They need to be: Identified; sketched and defined; evaluated and the *few most attractive selected;* tentative schdules and "maps" for their development worked out.

The maps should, while general, cover the entire process of problem definition, system concept creation, alternative identification, advanced development of prototype, successful operation, product development, market proving, tooling and population changeover. Much effort must be addressed to improving efficiency, reducing cost and improving reliability. A milestone in time for the achievement of each critical step needs to be determined and parallel-path approaches for some of the more crucial and difficult elements established. The plan ought to reflect both the optimism of "sponsors and the intentional critique of "devil's advocates". Although it is impossible to protect a development program precisely, the path to be followed can be envisioned reasonably well and failure to approximate the targeted progress along one route may well indicate necessity to emphasize another.

MANAGEMENT OF CHANGE TO THE 2000-PLUS A.D. MOBILE-DISPERSED POWER SYSTEM

The shift to the 2000+ A.D. system constitutes a new kind of challenge for mankind—*the effective guidance and management of change of large dynamic systems* with long characteristic times, to achieve goals acceptable to a society of individuals, both as individuals and as a whole. It will be the largest such

change and proceed at the fastest rate in mankind's history. Other similar system-management problems can build on the experience gained in solving this one; evidence of progress on this example should increase the credibility of the "establishment" and increase the stability of society. (105)

Management of the 2000+ A.D. mobile-dispersed power system must accommodate the facts that:

(1) It's the biggest system and biggest change that mankind has ever experienced; it has great inertia and long lead times.

(2) Management is polycentric; the system is fragmented into various fuel supply entities and regulatory entities, each with different requirements. They have been kept at "arm's length" by law and tradition.

(3) The environment and potentially applicable technology are continually changing.

(4) Commercial motivation is limited because time to commercialization is so long that patents are virtually worthless and proprietary technology diffuses or decays.

(5) The "free market" or "futures market" system of evaluation and allocation of resources has not been extended to effectively motivate, direct and coordinate developments with 25-year lead times.

(6) The situation and promise are not appreciated by the general public and, therefore, of political consequence; this must be changed through extensive and effective communication:

Of the nature of the system and underlying principles and constraints; of realistic alternatives for ultimate accommodation to a "value" system commonly acceptable to the public; of "a noble logical diagram (which) once recorded will be a living thing asserting itself with ever-growing insistency". (Daniel H. Burnham—1910.)

(7) 2000 A.D. is so far in the future that it is difficult to envision and today's political and industrial leaders will have disappeared from the scene before concrete results are widely recognized—therefore, a new dimension of industrial-social-political leadership and stewardship is required.

(8) Space and construction management experience, expressed in PERT charts, etc., can be adapted to the dispersed and polycentric control of the mobile-dispersed power system.

(9) Existing societal elements which have produced our current high level of technical/industrial development must be used because there isn't time to create a new world from scratch.

(10) Organization, motivation and funding are required.

Awakening recognition to the need to respond to the energy crisis is evidenced in legislation introduced by Senators Magnuson and Jackson and Congressman Wayman (126). It needs to give proper emphasis to mobile-dispersed power and the recognition of technological/industrial impact that lead to creation of Congress' Office of Technology Assessment (106–107).

"ENERGY-ECOLOGY CYBERNETICS CORPORATION"

One possible mechanism for improving present guidance or management of the 2000+ A.D. mobile-dispersed power system is a mixed economy corporation like COMSAT (Communications Satellite Corporation)—an *Energy and Ecology Cybernetics Corporation* (E^2C^2) (108). Its role would include:

(1) Evaluating, summarizing and communicating pertinent information;

(2) Facilitating establishment of concrete, realistic and socially accepted goals and a "map" of the scientific-technical-industrial-commercial development milestones and timetables that must be passed to reach them;

(3) Motivating efforts to reach the early milestone;

(4) Integrating, expanding and improving understanding and guidance of the entire system using a suitable model of it;

Its influence would be primarily through leadership based on understanding and exposition of the system and goal, rather than authoritarian imposition of control.

The future U.S. "Social-Industrial Complex" has been described as a "hybrid economy, part free enterprise and part governmentally controlled" of great complexity, interdependence and technology (109). President Nixon has called for effective teamwork, recognizing that "the sheer size (and lead-lag time) of some developmental projects is beyond the reach of private firms." (110) In addition, some developments require coordinated application of capability resident in different private firms. Establishment of E^2C^2 would be compatible with such viewpoints.

E^2C^2 must have responsible and capable *Directors* from the fuel industry, the engine industry, labor, user groups, the government, the academic community, the public at large and appropriate professional societies. It should attract the concentrated attention and efforts of the spectrum of capable and experienced professionals, who must cooperate to create the desired better system. While some of the participants might be in dispersed locations, a nucleus and attention, communication and cooperation need to be concentrated.

The information function should be freely accessible and professional to establish creditbility. Information must be reviewed and summarized with a skeptical and open mind with provision for minority views and devil's advocate critique of conclusions. The results must be summarized and communicated in a variety of understandable forms so that the variety of publics will understand the information, accept the need to carry out substantial work and support the necessary allocation of resources.

Communication forms would include technical society papers and panels, legislative testimony, business school case studies, technical and management theses, college and high school term papers, newspaper and magazine articles, TV shows, games to teach concepts ("The Energy Crisis" and "Delayed Effects"), Earth Day contributions, and primary grade indoctrination of the next generation.

Effective communication should bring the public to understand the energy/environment system and its management as evidence of mankind's progress and not as the devil and the surrender of individual freedom to the computer in "1984". Effective communication to the general public would require some particularly imaginative work. But it would be intellectually stimulating for both technical and media professionals, as well as for the over "soap-operated" and "situation-comedied" public which has a thirst for intellectual substance.

Establishment of the ultimate goal, the milestones on the way to it and the features of the target systems, in itself, would substantially motivate progress. In addition, early stages of progress could be stimulated through award of prizes for achievement of early milestones. Such awards could be limited to those milestones too far in advance of commercialization to be rewarded by patent coverage of other commercialization. Use of prizes, rather than payment for work done, should maintain individual initiative and flexibility and minimize the delays of predictive evaluations via "closed club" or bureaucracy.

E^2C^2 support ultmately must come from the public and users, because they recognize that the value is greater than the cost of developing, organizing and applying it. But the time scale of such impacts is long; so *initial* funding is required. Foundations seek ways to accomplish things that won't get done any other way; they could reasonably fund the earliest steps. Universities encourage work like this, because of their orientation to pure learning and long time projects. A separation tax on irreplaceable resources, such as crude oil or coal, is another possibility; a cent per barrel would yield $50mm/yr. and fund substantial E^2C^2 R & D activity. That would be a reasonable burden on users to fund development of intellectual substitutes for the irreplaceable resources consumed. The engine and fuel industries and professions through the American Petroleum Institute, the Coordinating Research Council, or the Society of Automotive Engineers should provide support and leadership. The later states of commercialization would have shorter time horizons and would be readily funded by normal commercial means. Ultimately, capital requirements will be large, and pension funds should consider the suitability of investing in the fuel processing projects.

A central organizing feature of E^2C^2 should be a dynamic model (64, 111–117) of the energy/environment system with "feed-forward" (108) characteristics. It would reflect the counter-intuitive and dynamic behavior of the system and yield a feed-forward view of the effects of legislative/regulatory policy decisions to permit intelligent system management. For example, it might be used to determine the minimum cost price-stimulus schedule required to obtain the necessary domestic oil and gas production schedule and to minimize nonproductive windfalls resulting from regulatory actions. It would reflect the very complicated and separated managerial, technical (118), production, financial and market aspects of governmental, industrial, user and environmental components, outlined in Figure 7 and/or as treated by White (52, 57). It would indicate how various alternatives would affect the whole system and parts of it.

It could be used in the academic or industrial-technical fields to stimulate creation and evaluation of concepts. It might be used by the financial community to better understand the dynamics and guide investments.

The model should be assembled on a modular, semi-custom, building-block basis and be subject to continual evaluation and testing against both judgment and observation. The model ought to include the effect of the model itself on management-decisions, processes and response times; once accepted, it will change them and tend to behave as a self-fulfilling prophecy.

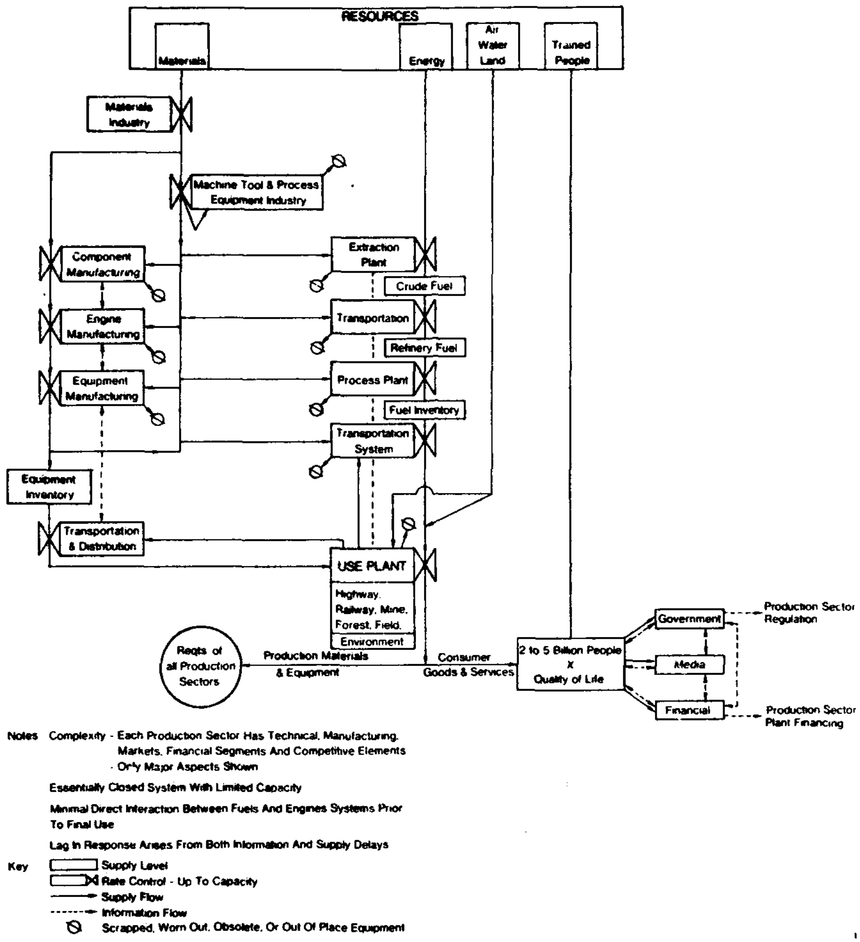


FIGURE 7.—The Mobile-Dispersed Power System.

Provision of easily understood interfaces with users and provision for their easy control and manipulation of the model is of *primary importance*. Practical full awareness and use of the model by all potential users, on a minimal cost basis, is a requisite for major impact and the criterion of its success. It is to be expected its greatest benefits, like those of other models, may be in training students and managers and in managing transients (which are more prevalent than steady-state operation) and oscillation caused by information feed-back.

The model cannot create the best solution to the problem; such synthesis requires the highest order of human intellectual endeavor. But it can make it possible for more to participate in that endeavor and for more possibilities to be explored more realistically.

CONCLUSION

Mankind's way of satisfying needs for mobile-dispersed power will probably change about 2000 A.D. as costs of finding and producing petroleum rise substantially. Because of the long lead times of the large, complex and highly-developed

resource-fuel-engine-use system, advanced development of the new one should start now with an evolving vision of the likely system.

The mobile-dispersed power system is a larger and more highly-developed human/society activity than has ever been changed as fast before; so, it requires new "management" techniques. A realistic course of action must be developed and understood, supported and guided by the public to serve its values. An Energy and Ecology Cybernetics Corporation is one mechanism for guidance and motivation of the necessary effort. A dynamic model of the system is one tool.

ACKNOWLEDGEMENTS

Development of the best system for 2000+ A.D. mobile and dispersed power is important and requires continuing attention and changes as assumptions and perceptions are refined. This paper is no more than a beginning. It is hoped that it will be a stimulus to the readers' thinking, to initiation of a suitable course of action and to our overall effort to provide future generations with their mobile-dispersed power system.

It is impossible to remember and identify the origin of most ideas. While the author takes responsibility for the ideas in this paper, it's only fair to acknowledge that the ideas would not have developed without the interaction and help of others. The list of references indicates some of the origins. In addition, it's appropriate to acknowledge the contributions of: Earl Bartholomew, George Bugliarello, P. S. Myers, R. Bruce Foster, D. P. Carver, Robert W. Richardson, W. T. Lyn, and C. Lyle Cummins, Jr.

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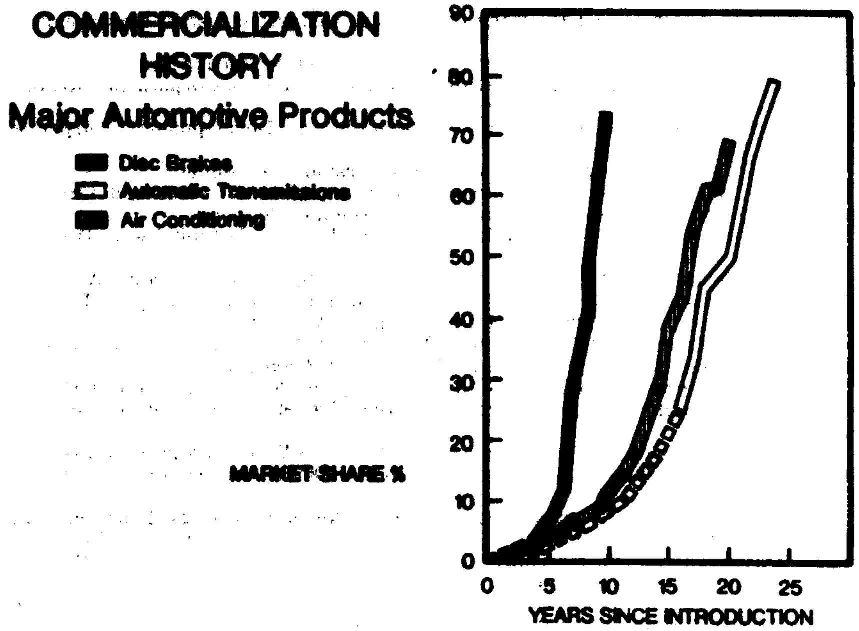
Mr. RICHARDSON. In anticipation of eventual depletion of our petroleum resources, Dr. Eltinge discusses the very long leadtimes required to change over to a new engine and compatible energy system. Using generally accepted leadtimes for the individual development tasks involved, the total development time ranges from 25 to 60 years. The point Dr. Eltinge makes is that we need to start now if we are to have a new mobile power/fuel system ready for the 21st century. Further, he suggests the need for creation of an ongoing management system conducive to dealing with the very long development time which is beyond the effective interest span of both industrial and Government leaders.

Actual historical data on rate of commercialization correlates quite well with these long leadtimes (slide 11).



SLIDE 11

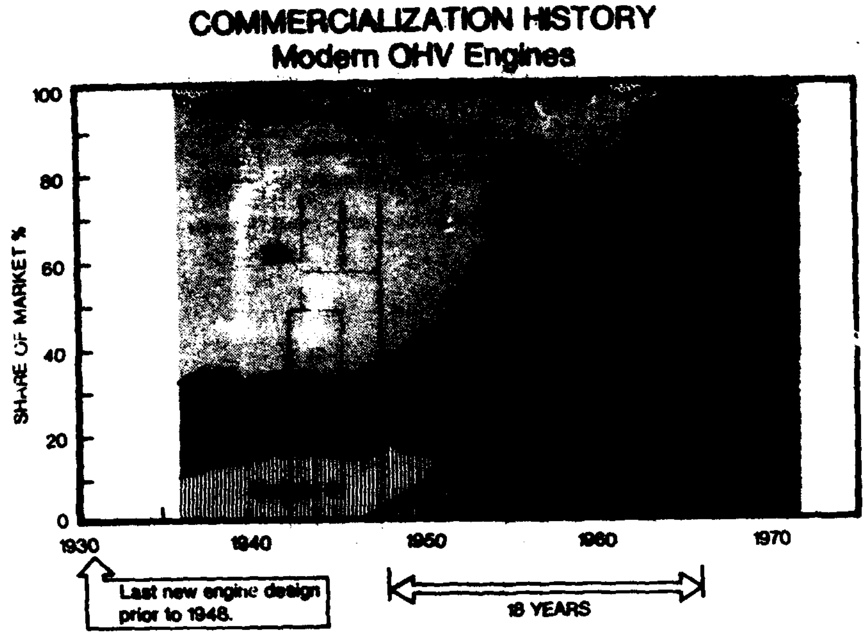
It shows that the automatic transmission took 20 years; air-conditioning, 17 years; and disc brakes, 9 years from successful introduction to reach 50 percent penetration of the new-car market. All had been marketed unsuccessfully in the United States many years earlier.

Power steering and power brakes took 14 and 17 years respectively to reach 50 percent market penetration. These are examples of the most successful products. Many lesser successes have not reached 10 percent and some have approached 10 percent only after 15 to 25 years.

This slide (slide 12) shows how the engine market mix has changed since the mid-1930's. Superimposed is a curve showing the transition to the modern engine. This change started in 1948 and was not complete until 1966—18 years later—evolutionary, not revolutionary.

In 1948, the industry was due for a change; the last previous significant new engine was introduced 17 years earlier and some engines were approaching 30 years of age. Production tooling was largely obsolete and worn out. Furthermore, substantial R. & D. had taken place on engines and considerably higher octane fuels had become available, both largely in response to wartime aircraft needs.

The steep increase in the mid-1950's of both modern engines and eight-cylinder engines seems to parallel the horsepower race. Pent-up demand and consumer savings resulting from two wars helped fuel this growth. Had a long term smooth growth curve for V–8 engines taken place, the transition curve would probably have been a typical smooth S-curve with the midpoint about 1955.



SLIDE 12

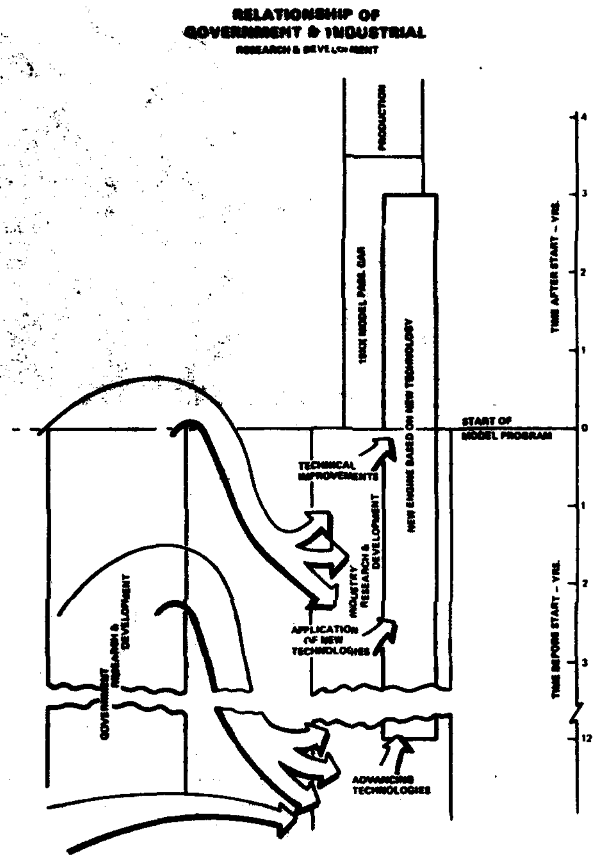
This early growth represents the demonstrated capacity of the industry for major substantial engine change and tends to suggest this conversion to modern OHV engine could probably have been completed in 10 to 12 years.

Now we will superimpose a curve showing the transition to the modern engine. The change was not complete until 1966, 18 years later. The early rapid conversion through the mid-1950's represents the demonstrated capacity of the industry for major substantial engine changes and tends to suggest this conversion to modern overhead valve engines could probably have been completed in 10 to 12 years.

That sort of a change is considerably less than what would be involved in changing to an all new powerplant such as a turbine engine.

I would like to now return to the format of the previous leadtime charts.

This slide (slide 13) shows the relationship between Government and industrial research and development as they affect automotive product development. Government-funded research shown on the left.



SLIDE 13

Development of automotive engines outside the industry adds to leadtime because the external development must be fed into the auto industry in the R. & D. phase several years prior to the start of a new model program resulting in duplication of effort.

The industry cannot be expected to make massive capital investments in tooling without first satisfying itself that they have a commercially feasible product. This means they must first have extensive experience with it. Any outside research can be more easily transferred to the industry with less increase in leadtime in its early phases, as the nearly horizontal arrow shows on the bottom of the chart.

This suggests that outside research is most effectively applied to basic technologies such as materials or processes.

For example, advanced, low cost, producible, high temperature materials appear to be crucial to the successful development of economically feasible turbine and Stirling engines.

Government-conducted or Government-sponsored research can therefore most effectively be applied in the premilinary basic technology areas where there are apparently very long leadtimes and very high risks. That is, those areas where industry is not likely to commit substantial effort.

The very well intentioned Clean Air Act of 1970, passed by a rightfully concerned Congress, because it did not adequately consider these leadtime requirements, actually worked to divert industrial resources from alternate poweplant R. & D. work to work on catalytic cleanup of the present internal combustion engines.

I point this out not to be critical of Congress but to indicate the importance of considering thoroughly the potential impact of our decisions and to recognize the very long leadtime involved. The cost of impatience can be very high. Haste makes waste here as in other aspects of our lives. In our impatience as a society to have clean air, low noise, and conservation of resources, including energy, we may pay an extremely high impatience cost without actually achieving our objective or even a significant portion of it.

When we try to reduce lead times, cost and risk increases.

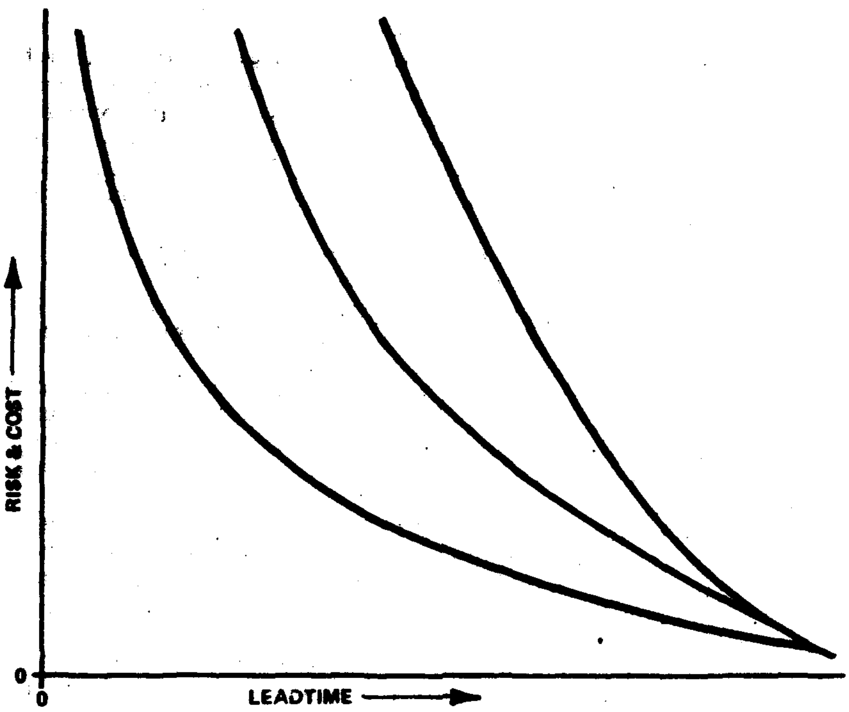
They usually increase exponentially. A small reduction in leadtime can often be had for only a small increase in risk and a small cost penalty. But large reductions in leadtimes result in very high risks and cost penalties.

I share your frustrations with these long leadtimes. I have spent my entire professional career attempting to instigate change. It is a difficult, frustrating job—were it not so, however, society would likely be in continuous chaos. While the disciplines of our system tend to slow and impede change, this is very often for our best interest.

While this is a disadvantage in some instances, we have not, however, been able to conceive a better system.

As previously mentioned, if a change is to occur or a new development to be used, then those with the ability to exploit it must be the ones to pursue it either of their own volition or by encouragement in the form of incentives or persuasion in the form of regulation.

LEADTIME VS. RISK



SLIDE 14

The profit motive inherent in the free enterprise system generally works to provide a market demanded product or service as efficiently as possible within the basic ground rules of business, law, or regulation. The proper role of Government appears to be to first identify either alone, but preferably in combination with industry and the academic community, long range needs, determine appropriate public policy, and stimulate appropriate responses through incentives and ultimately through the setting of realistic performance standards to move industry in the direction of changed public policy.

In other words, modify the ground rules and then let industry go to work. The Federal role appears to be primarily needed in areas such as public health where the marketplace feedback of the effects of emissions on health is too random and too remote to be reflected in product design. In this area, scientifically supported, realistic performance standards appear to be a proper role for Government.

If the rate of progress is deemed not sufficient to meet society's needs or public policy, then judicious use of incentives, perhaps increased investment tax credits on facilities for new technology engine production, combined with well-founded performance standards can help, but not likely with a very drastic effect.

I do not suggest such tax incentives from a studied point of view but only as a recurring thought for further consideration. Even large scale effective R. & D. does not guarantee that results will be exploited.

Expanded R. & D., no matter how effective, will not cause the exploitation of new development by itself.

Industry must have the incentive to make the massive capital investments necessary to bring promising development projects to commercial fruition. This is why instigating change is such a frustrating job. You have many technical successes, but business failures.

I would like now to discuss with you the detailed results of our engine study (slide 15).

Relative Importance of Selection Parameter

Passenger Cars — Compared with 4-Cycle Spark Ignition Piston Engine

	Wankel	*Turbine	Stirling	Stratified Charge	Diesel
Flexibility	−	+	+	0	−
Smoothness	+	++	++	0	−
Emissions	0	+	++	+	+
Cost	−	−	−	?	−
Noise	0	+	++	0	−
Weight	+	+	0	−	−
Size	+	0	−	−	−
Maintenance	0	+	+	0	+
Fuel Consumption	−	−	++	+	++
Durability	−	?	+	0	+

Advantage (+) or Disadvantage (−) *Two-Shaft Regenerative 1900 F Turbine Inlet Temperature

SLIDE 15

In our investigation we considered five new engine types as serious contenders, the Wankel, turbine, Stirling, stratified charge, and diesel engines. We did not consider steam engines as a serious contender based on previous studies indicating several shortcomings, notably, high fuel consumption. Electric vehicles were also discounted due to the state of technology being woefully inadequate and the economics generally unattractive.

I might just ad lib here to mention that we are the world's largest producers of electric vehicles—electric forklift trucks. We have made fairly thorough studies.

Mr. BROWN. Your company is the largest?

Mr. RICHARDSON. Yes.

These five new engine types competing for future automotive use are compared with today's four-cycle, spark-ignition piston engine on each of these parameters. Each engine was rated better, plus; worse, minus; or equal, zero, to the present gasoline engine. For a new engine or a new product of any kind to succeed in a mature market, it needs to be substantially better, not just equal or marginally better. The printed paper covers these comparisons in much more detail.

The Wankel, despite much recent fanfare, has little to offer in the three important social areas and uses substantially more fuel, 30 to 40 percent more. It is also a more costly and less flexible engine and has poorer durability characteristics.

The Wankel is a very smooth engine and is smaller and lighter, but nowhere near as much as often claimed.

The turbine engine is quieter and can have very low emissions but has higher fuel consumption. This may ultimately be overcome with advanced designs but a whole new material technology development is first required. It is lighter, smoother and more flexible, should require less maintenance, but is costly and its durability has not been proven for automotive applications. The turbine requires considerable additional development before it could enter volume production.

The Stirling engine has the lowest fuel consumption, lowest emissions, and the lowest noise of any known engine. It is potentially capable of burning any fuel since it is an external combustion engine. The Stirling engine also has flexibility, smoothness, maintenance and durability advantages, but tends to be somewhat bulky and very costly. It is at an early state of development, and introduction in high volume production is not likely until at least the mideighties.

Stratified charge engines could be introduced relatively quickly into production as it is a variation of today's piston engine.

The stratified charge engine provides a better tradeoff between fuel consumption and exhaust emissions. It appears to be capable of meeting the interim 1975 and 1976 emissions standards while equalling or bettering today's engines' fuel economy.

Stratified charge engines have a disadvantage in that their specific power output is somewhat less than conventional engines, resulting in lower performance cars or an increase in engine size.

Diesel engines have low fuel consumption and low emissions of controlled pollutants but high emission of smoke, odor, and noise. They require less maintenance and have a long life but are at a disadvantage in all other characteristics.

On balance, therefore, the stratified charge reciprocating engine appears to be the leading near-term challenger and the Stirling engine, the leading long-term contender.

Let us now examine our projection on the rate of commercialization of each engine type. These projections are shown in a composite chart, figure 16.

First we will show the range of Wankel penetration. In 1985 it could be from as little as zero up to 23 percent. I think this shows up better on the slide. And in 1980 it could be from about 3 to 13 percent.

And next for the turbine and Stirling, engines with penetration again from none up to about 8 percent in 1985. The balance of the market, the reciprocating piston engine, is obtained by subtracting the sum or turbine and Wankel minimum and maximum penetrations from 100 percent. The piston engine would have a market share of at least 69 percent and could conceivably take the whole market in 1985. You will note that the maximum piston engine market share in 1980 is 97 percent due to the forecast minimum Wankel penetration.

These charts were prepared quite some time ago. And if I were to make that projection today, I would give the Wankel less chance than is shown here.

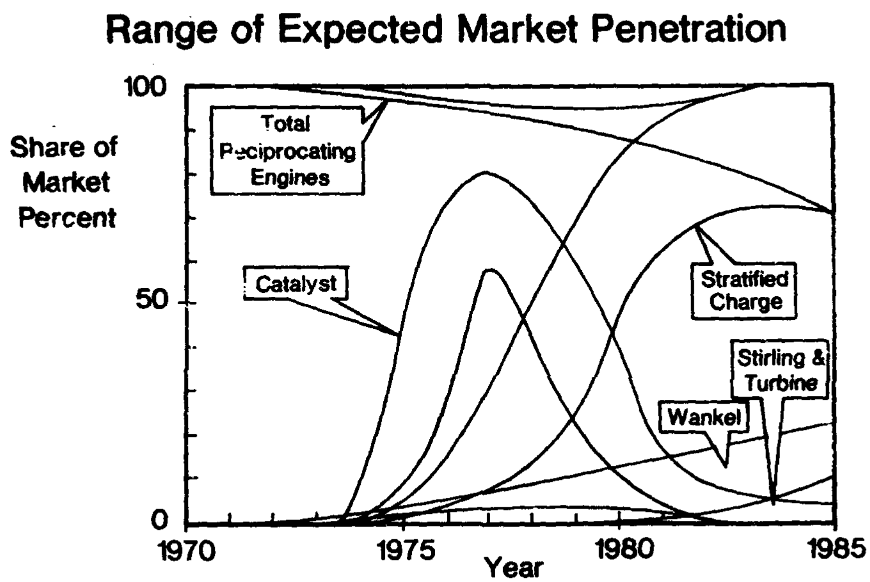
Now what will these piston engines be like?

We have attempted to construct the shorter term picture. The number of catalyst controlled engines will be substantially lower than shown, if emission standards are liberalized. The picture for 1976 and beyond is still very unsettled.

The catalyst curve shows an early decline as the stratified charge engine comes into use.

The stratified charge engine may indeed prove sufficiently attractive to not only take over this whole reciprocating engine segment, at least 69 percent of the total, but to even recapture the small segment lost to the Wankel in the mid- and late-1970's.

When we put the total picture together it looks like this (slide 16).



SLIDE 16

Now that is the chart that is in the prepared statement.

Our conclusions from this study therefore are that reciprocating piston engines will remain dominant well into the 1980's. There still is considerable uncertainty as to the choice and rate of commercialization of specific new engines, but no revolutions are likely in the near future.

Vehicle and engine manufacturers will continue to approach change with caution and will follow conservation introduction and commercialization strategies. Economics will continue to be the dominant influencing factor. But, social requirements, especially fuel consumption, will become much more significant in influencing change to different engines.

We hope that in this brief statement we have been able to provide some helpful perspective on the nature and status of automotive engine R. & D.

We would like to reiterate our position that industry through the discipline of the marketplace is in the best position by far to balance the many, often competing, requirements for automotive engines. Therefore, they can accomplish this task more efficiently and more quickly than anyone outside the industry and can maintain technology transfer problems.

The Government's primary role should be to identify long-range needs, especially those where free market feedback tends to be remote, to establish appropriate public policy and to provide incentives for industry to meet these needs and where necessary, establish soundly based performance standards.

To carry out its role, Government must be more aware of the long leadtime involved in the innovative process and to recognize that we often have to live for a very long time with our major decisions.

Thank you very much.

Mr. BROWN. I want to thank you, Mr. Richardson. I think you have undoubtedly given us the most detailed analysis of the specifics of what we can expect in new engine development, more so than any of our witnesses have given us. I appreciate that very much. I think that will be a very valuable contribution to the record which the committee is accumulating here.

I note your description of the Government's role and I think it is a reasoned and probably generally acceptable definition under normal conditions. I have some questions, however, as to whether that role may be completely adequate under conditions which you might describe as abnormal conditions which you might describe as a crisis situation, or in mathematics where we have curves which are discontinuous. This, of course, is always the area which causes us, as political figures, the greatest amount of difficulty. We may be in that situation with regard to automobile systems because of the great pressure which developed first, over the emission situation and then, second, over the fuel situation.

I am not sure that politically speaking we can tolerate a situation where the leadtimes, which I think you have described very accurately, are permitted to run their normal course.

For example—and I would like to ask you to comment on this—many of the people in southern California became concerned about the emissions problem, basically the smog problem, 20 years ago or longer.

You are talking now about leadtimes from the present to develop a suitable emission control system, or a nonpolluting engine, which will run another 15 or 20 years, or longer, in order to get it into general use. Those of us in southern California are looking back 20 years and saying, "Why didn't the leadtime start then so we have something now?" The industry, in other words, seems to have an inertia in some of these areas.

Mr. RICHARDSON. I think that is an excellent way to describe it. This system is extremely large and does have a very high inertia. I think that is one of the points that Dr. Eltinge made extremely well in his paper. If the inertia of the auto industry to a new motive systems is large then the inertia of the energy system to a crisis is probably a good deal greater. I do not mean that to indicate there is any sinister context in any of these industries. It happens in all of our society.

It provides a stabilizing influence which is probably for the best but it frustrates people like me who try to institute change.

But as I indicate in my testimony I am afraid that if those of us who want to make change were allowed to do so with no checks and balances that society would be in perpetual chaos.

Mr. BROWN. That is what they tell me in the Congress. [Laughter.]

Mr. RICHARDSON. I certainly appreciate the problems of the citizens of southern California. I have been there many times and I find it very unpleasant.

Of course, the problem developed over quite a period of time and it took quite a while to establish what the cause of it was. I believe it was approximately 20 or 21 years ago when the auto's role in this problem was identified. At that time it was one researcher who later turned out to be right but often we have research which is faulty. And before massive resources are committed you would like to feel confident you properly understand the problem. I think this is a proper role of certainly Government funded research—perhaps by universities—to identify the sorts of problems and to establish them with enough confidence that basic public policy can be established and appropriate responses instituted.

Certainly there may be times—I would think they would be rare—when situations are really of crisis proportions when public health and safety demands something drastically different from the use of our traditional mechanisms.

I think industry has demonstrated, if you go back to World War II, its competency to change very fast, not economically but very fast when there is an emergency situation.

Mr. BROWN. I am glad that you brought that point out. It has occurred to me and other members of the committee that there really is no question about their ability to change rapidly given recognition of the constraints. The conversion of the automobile industry from full production to zero production of automobiles and then to massive production of aircraft and tanks and other vehicles—and then to change back in an equally short period—that is an example of very massive change.

Mr. RICHARDSON. During World War II their massive population of aircraft was in tens of thousands of units and not in the millions as it is with automobiles, but it was still larger than what the aircraft industry was doing.

Mr. BROWN. The question which comes to us is are we at a point where it is necessary for the Government to change the parameters of the system in order to accelerate certain change which is vital to the public welfare. I can see that being done perhaps very drastically. It would not take but a single enactment prohibiting automobiles that had an efficiency less than 20 miles per gallon—or you could set a weight liimt or put a prohibitive tax on horsepower and this would make a major change in parameters of the system.

Mr. RICHARDSON. Certainly it is possible to do any number of those things. I tend to feel that those sorts of things are generally disruptive. If we are indeed concerned about our energy resources then I think the price of energy should reflect that and therefore the free market would control its usage. If energy indeed is running out then it should become nearer and dearer to us and we would expect to pay

more for it. That would discipline each one of us as to how to use it. It is very hard for one individual or a committee of individuals, no matter how well intentioned, to allocate resources or determine what is best for everybody.

We went through this exercise internally just over the energy situation this past winter and asked ourselves in my department if we were responsible for allocating a given amount of fuel among the employees in our research center how would we do it? We concluded very quickly that we did not want the job and that we could not do it anyway near as well as the free market place no matter how well we attempted to do it. That was a committee of about five of us. I doubt very much whether that degree of thought will be given to allocating resources to individuals in any administrative system.

Mr. BROWN. Your example illustrates a very good point. Most of us when we come up against a complex problem for which we do not have solutions prefer to have some external solution which we can take. And the free market is an external solution which in our culture is assumed to be uniformly good.

If however we have a question of whether the free market mechanism is actually working then that raises more serious problems.

Mr. RICHARDSON. I would not say it is uniformly good. There are many mistakes it makes and it is not perfect but I think that it is better than anything else which has been devised.

Mr. BROWN. We say that about our system of government, too.

Mr. RICHARDSON. Right. We can find inefficiencies in either of these.

Mr. BROWN. The problem we find in meeting the energy shortage by the free market mechanism—just as we do in solving the pollution problem by a free market mechanism—is that there are too many examples where total costs are not being internalized but some portion of them are being absorbed publicly. This distorts the free market mechanism.

In some cases there are other distortions of the free market. You recall in the automobile case the Department of Justice brought suit under the antitrust laws with regard to emission controls on the grounds that the free market system was not working there. It was never proven, of course, but there was evidence that there was some collusion on the part of the industry to prevent the marketing or full development of emission control systems.

These are the kind of distortions we are called upon to look into and see if we can counteract them in one fashion or another. Frankly I am becoming more and more disillusioned with our ability to do so, but I do not think we can afford to stop trying, which is of course the basis for legislative efforts such as the bill we have before us.

I would appreciate knowing a little bit more about the work of your company. You mentioned your involvement with electric vehicles, which struck a chord.

Mr. RICHARDSON. We produce forklift trucks. We just happen to make more electric forklift trucks than anyone in the world. That is the primary electric vehicle which is in use in the world. They are based on a pretty ancient technology. They use lead acid batteries and DC traction motors. Probably the most significant innovation has been the solid state SCR control going back about a decade.

Mr. BROWN. Do you have a market analysis unit which seeks to determine whether there is likely to become a market for other types of electric vehicles in which your company could participate?

Mr. RICHARDSON. We have in our department made studies of electric vehicles going back to, I think, the earliest was 1966.

We essentially concluded that the electric vehicle could fill a small role but we saw no real economic reason why it should and we do not feel that it will be a net benefit from either a pollution or an energy standpoint. It transfers the problems from one location to another. It is a different type of pollution problem. I for one am not able to adequately weigh the effect of whether sulfur oxides emissions from a powerplant chimney or hydrocarbon emissions from thousands of vehicles' tailpipes—which is the worst situation.

I can apply some reasoning and under various circumstances one is worse and under other circumstances the other is worse. But I do not think there is a significant net gain to be had that way unless we remove the electric powerplants to remote areas. And traditionally that is not what we have done.

Mr. BROWN. Yesterday in connection with electric vehicles we discussed parameter changes which would require electric vehicles, just as in some warehouse situations you require electric forklift trucks. We may be getting into that situation in certain urban areas where we may find that we need vehicles with those characteristics in urban areas, and that would tend to enlarge the market.

Mr. RICHARDSON. Certainly if other types of vehicles were prohibited it would. But this technology is woefully inadequate to make a very practical electrical vehicle by the standards we have known.

My understanding of the pollution problem is that we are not now nor are we likely to approach a situation which requires something like that. I certainly share the concern of the people who have to live with it. I think progress has been made and I think considerably more progress is in the offing. It took us a long time to get into the problem and it is likely to take us a fair amount of time to get out.

Mr. BROWN. Just another word or two about NASA's role which is the subject of this legislation. You have said fairly succinctly that the primary role of the Government should be to identify long-range needs especially where free market feedback tends to be unable to establish a public policy to provide incentives for industry to meet these needs, and where necessary establish soundly based performance standards. You have indicated earlier that the proper role is more in the basic research area rather than the actual development and marketing area.

Mr. RICHARDSON. I think an advancing base of technology would be quite useful to the automobile industry as far as new types of engines are concerned and to all elements to our society.

Mr. BROWN. In view of the excellent presentation you have given about the need for, and the elements of, some other types of engines that have the characteristics you have indicated, I presume you would agree that NASA could play a useful role in solving some of the problems involved in shortening the leadtime for development?

Mr. RICHARDSON. I certainly think they can play a role in either their own in-house work on basic technology or on what they manage through their contractors. From the standpoint that this technology,

the basic technology, is brought along sooner, it will certainly help with the leadtime. I do not think they can contribute very effectively to the later development phases. I think they can provide a reservoir of technology which the industry can more quickly adapt.

Mr. BROWN. Of course we are looking at the experience that NASA has had in the parallel development of aircraft engines. We have heard no adverse comments to speak of with regard to the importance of the role and the contribution that they have made through the NASA laboratories, recognizing of course that aircraft and automobile are two different industries. It has been our view that there still might be some parallelism which could be usefully extended. You wouldn't take too much issue with that would you?

Mr. RICHARDSON. Probably not a great deal. I think there is a marked difference between the aircraft industry and the auto industry. The aircraft industry is much more highly Government regulated and Government supported in one way or another. I do not claim to be an expert on NASA's contributions or their role there. Although, my understanding is that their developments have been primarily by contractors and not by NASA itself. I think that in days past with the old NASA that more of it was done in their labs, but recently it has been primarily through contractors. If I understand correctly, they have been the administrative organization to dispense or disburse Government funds and manage total resources. I have no quarrel with that.

Mr. BROWN. I don't want to belabor this. I think your statement very clearly sets forth your own position on this. As I say, it is one of the best presentations we have had particularly in its contribution to a realistic evaluation of future engine developments.

I want to thank you very much.

Mr. Hammill would like to ask you a question.

Mr. HAMMILL. Mr. Richardson you mentioned in your statement the long leadtimes which are required for introducing innovations into automobiles or automobile engines.

Mr. RICHARDSON. It is not just limited to the automobile.

Mr. HAMMILL. A previous witness noted that many, or perhaps most, of the important innovations in automobiles have been generated by foreign auto companies rather than by the U.S. auto industry. Do you think that is a fair assessment, and, if so, why do you think it happens that way?

Mr. RICHARDSON. I do not think it is a totally fair assessment. I think there is some validity to it. I think it partially happens because the requirements of the marketplace in other countries are different from what they are here. There are things we can occasionally borrow from them and vice versa. I think, in general, automotive technology has gone in the other direction, that the state of automotive technology elsewhere in the world has generally been behind, from an overall consumer, standpoint, behind the United States.

If you talk about very high performance engines and things like this, the marketplace in Europe and Japan, because of the cost of fuel and taxes, has forced the development of high-output small engines intended for smaller vehicles. So for perhaps today's needs some of what they have had for years would better fit our needs here. There may indeed be some transfer possible in this direction. But in terms

of the general functional role of the automobile I believe they have generally been behind us, especially in terms of safety and comfort and noise level and so on. I have owned several foreign cars mainly for their high-performance, sports-type cars.

Mr. HAMMILL. But with fuel shortages predicted for the future, the marketplace may force the American industry into smaller cars.

Mr. RICHARDSON. It is indeed doing that at a very rapid rate. There have been rather massive expenditures to convert assembly plants from big cars to small cars on a nonefficient and panic basis. I guess it is efficient if you are not selling cars. I think this is indicative of the fact that the free marketplace in general does work and does cause response. But they cannot change overnight. I know of no way that it can be done. It cannot be done by edict or it cannot be done by committing massive resources. That helps but they have to be effectively utilized.

Mr. GOLDWATER. It appears to me that the industry is responding but there is nothing new. All they are doing is compacting something we have had for many years and there is nothing really new coming out.

Mr. RICHARDSON. I think there are new things coming out all the time. I think some of this role has been restricted by the very great effort the industry has been forced to spend in the areas of emissions and safety. The research and development resources have been heavily committed to those two areas in the past several years.

Mr. GOLDWATER. In other words, their efforts have been misdirected or diverted on a temporary basis to respond to sort of an ancillary problem that in essence prevents them from directing their efforts to the big overall problem?

Mr. RICHARDSON. I would not say to an ancillary problem. Those are very serious problems which the resources are directed to. However, I think it has taken the lion's share of their R. & D. effort. As I indicated in my testimony, the attempt to meet the requirements of the Clean Air Act of 1970 I am sure diverted some of the resources which would have gone to alternate engines. There was no way under the time constraints that they could develop alternate engines. Hindsight, of course, is 20-20.

Mr. GOLDWATER. But using hindsight do you feel that if we had used that same amount time and perhaps the same amount of dollars in tackling the solutions to an alternative type of power, instead of working on the emission-type devices, we would have in fact been able to come up with something which would solve all of the problems?

Mr. RICHARDSON. Certainly not by today but will have gotten there sooner than we will with the present system.

I think perhaps had a more effective compromise on emissions standards been set and a date set for the early 1980's that it would have been possible to have alternate engines in production by that time. I see no way it will happen now.

Mr. GOLDWATER. It seems to me like a case of overreaction by Government.

Mr. RICHARDSON. I think it was probably a hasty overreaction. I think it was a case where you looked at one problem and attempted to solve it without thoroughly considering all of the ramifications—that was what I tried to bring out in my prepared statement. There are

many parameters which have to be looked at and they have to be balanced.

The steam engine is a good example. It has low-emission potential but it has very high fuel consumption problems. Five years ago we were not worrying about fuel consumption and it made sense to look at that engine. But I think the day is long past when it makes sense to continue to pour much effort into that. The Government is still doing that.

Mr. HAMMILL. One last question if I may, sir.

Mr. BROWN. Go ahead.

Mr. HAMMILL. Another previous witness expressed the opinion that the automobile industry allocates less of its resources to support research and development work than other industries in the United States. I recognize we are comparing apples to oranges here, but would you agree that that is so, and can you think of a reason for it?

Mr. RICHARDSON. I am sure that is true in regard to some industries. I do not have the numbers here and certainly would want to look at them. I am sure they spend more than many other industries. It depends a great deal on the type of industry. If you are in an extremely high technology industry—the aerospace industry spends more but not necessarily effectively. If the marketplace will not reward the guy who spends the money for his innovations, he will go out of business doing it. It makes him noncompetitive with his competitors. The industry can only really effectively go at the rate the marketplace will accept unless there are some new ground rules created by Government which forces them in another direction and protects them from the reaction of the marketplace if they do it.

Mr. HAMMILL. Marketplace considerations then may dictate that the automobile industry put a lot more money into cosmetic changes, style changes, and that sort of thing than in substantive innovations. Does that seem to you to be the case?

Mr. RICHARDSON. I take it you are referring to the annual model change.

Mr. HAMMILL. That sort of thing. Fins on fenders and things like that which require a lot of new tooling, whereas the stratified charge engine, for example, is something which has evidently not occupied the talents or commanded the resources of Detroit.

Mr. RICHARDSON. I think the major companies have had stratified charge engine programs on and off for decades. It is just that the advantages of the stratified charge did not appear to be very significant in the past. Major effort was not aimed at fuel economy over the years. Fuel economy was not of significant importance and consumers would not pay for it, because energy was cheap enough to warrant not going to that engine. The ground rules have indeed changed and the stratified charge engine in today's climate I think makes great sense to industry. In your earlier comment you were probably referring to the fact that Honda developed one version of it. That basic version was developed in England in 1915 by Harry Ricardo. It was not very satisfactory. It had been worked on in this country off and on at various times. We worked on it in our own laboratories, a single cylinder version, a little more than 2 years ago and had some attractive results from it. We were not aware of Honda's work at the time we did that. We obviously have not committed anywhere near the resources to it which they have. We are

not in the engine business. It was just to back up our parts business. I can assure you there is an awful lot of interest in that engine everywhere in the world.

Mr. BROWN. Any further questions?

Mr. GOLDWATER. Yes, I have one.

I apologize for not being here for your testimony but I will look forward to looking over it when I get back to my office.

But you seemingly have looked into this whole concept of these problems in great depth. I am sure you have some opinions as to why we are where we are. We have discussed them and talked about them a little bit. But I would like to know why we in this country have developed large cars and big engines which consume a lot of fuel and go very fast, whereas in Europe and Japan and Italy they have in essence gone the other way? What phenomenon dictated this? You say the automobile industry responds to the market. Was this something that really the market dictated? And if it did, why did it dictate it?

Mr. RICHARDSON. First let me make one comment on your point relative to speed. I think we have the same speed capability in vehicles throughout the world. Vehicles in Europe and in Japan are indeed capable of being driven very fast, and in fact are.

Mr. GOLDWATER. But maybe not with the acceleration capabilities.

Mr. RICHARDSON. On the average that is true but there are vehicles in each part of the world which do have a high acceleration capability. They are perhaps less common overseas. I think this is simply an economic situation. The basic per capita income or standard of living in other areas in the world is nowhere near as high as it is here and therefore the consumer in other parts of the world has not been able to afford the level of luxury we have here. The cost of energy in both Europe and Japan has been very high compared to what it has been here, several times what we pay here.

Mr. GOLDWATER. The cost to the consumer.

Mr. RICHARDSON. Yes. And it is primarily due to a very high tax structure on fuel in other countries. Fuel has been very expensive. So this plus a basic lower economic level and lower standard of living has forced much more economical cars. The cost of operation and cost of fuel has been a much more important parameter.

Mr. GOLDWATER. So cheap fuel——

Mr. RICHARDSON. It has been a very bad thing.

Mr. GOLDWATER. In essence it has dictated what the market will be. So maybe one solution in this country would be to allow the price of the fuel to rise.

Mr. RICHARDSON. I think I indicated that earlier. I think the consumer should pay realistic prices for energy. I think we are only fooling ourselves and creating later problems if we are unrealistic.

Mr. BROWN. That question is not for the committee but I presume that means that you would agree the Government should not adopt policies which have the effect of depressing energy prices.

Mr. RICHARDSON. That is correct.

Mr. GOLDWATER. I think the marketplace will dictate what industry will respond to. And if the market dictates that we have better performing engines and less polluting engines and better fuel economy, then they are going to respond.

Mr. RICHARDSON. Certainly the energy shortages of this past winter, the unavailability of gas, has had a dramatic effect on the salability

of big cars and on the increased market for small cars. I think the marketplace has responded very quickly. Faster than industry.

Mr. GOLDWATER. Now on the difference in engines—in the United States it appears that we go into a very powerful kind of engine with lots of bulk power whereas the Japanese and Germans go in for the small engine with a lot of high rpm. They use high rpm whereas we use bulk power. Is there a reason for that? Is that true?

Mr. RICHARDSON. It is generally true. It is related to the economics I have previously mentioned. To get good fuel economy they go to a small lightweight vehicle which dictates a small engine, a smaller and lighter engine running at higher speeds. This saves on weight and saves on fuel consumption. Also the tax structure with which I am not familiar in detail, but I think it also tends—in many countries vehicles are taxed on the size of their engines. In fact in some States in this country—Massachusetts used to have a tax based on engine displacement. Or it was a fictitious displacement which they used.

Mr. BROWN. Thank you again Mr. Richardson. We have benefited considerably from your testimony. May I just ask, if we have additional questions from committee or staff, would you be willing to supply answers to written inquiries.

Mr. RICHARDSON. I would be happy to.

Mr. BROWN. Thank you.

Our next witness is Mr. John W. Bjerklie, Manager of Research and Development for the Hague International of South Portland, Maine. We are very pleased to have you here Mr. Bjerklie, and we are ready to receive your testimony in any way you wish to submit it.

[A biographical sketch of Mr. Bjerklie follows:]

JOHN W. BJERKLIE

Born in Grand Forks, North Dakota, on December 18, 1927. Served in the army from 1946 to 1948. Attended the University of North Dakota, and graduated from California Institute of Technology in 1951 with a Bachelor of Science Degree in Mechanical Engineering. Obtained a Master of Science Degree in Engineering from UCLA in 1958. Married to the former Marjorie C. Maninger of Pasadena, California. Four children—John, David, Kirsten, and Ellen.

PROFESSIONAL CAREER

Mr. Bjerklie worked as an analytical and development engineer at Marquardt Aircraft Company, AMF Turbo, Sundstrand Aviation, Mechanical Technology Inc., and is now Manager of Research and Development at Hague International in South Portland, Maine.

His entire career has been devoted to the origination and development of energy conversion devices. This has varied from combustion systems to power plant development, and has included system analysis of the energy and heat transfer aspects of many varieties of thermal systems.

Now, for Hague International, Mr. Bjerklie is developing low emission burners for heavy fuels and high temperature heat exchangers for conserving energy in oil-fired furnaces. He also serves as a consultant to the Committee on Motor Vehicle Emissions of the National Academy of Sciences where he is evaluating prospects of various alternative power plants for automobiles.

PROFESSIONAL ACTIVITIES, HONORS, AND AWARDS

Mr. Bjerklie received his BS degree with Honors at Caltech, is a member of TBII, national honorary engineering society. He was co-recipient of the Manley Award from SAE in 1964. He is a member of SAE, ASME, AAAS, and the Combustion Institute. He is a member of the Advanced Power Plant Committee of the SAE. For the past four years he has organized the SAE Impact Series of Panel discussions.

STATEMENT OF JOHN W. BJERKLIE, MANAGER OF R. & D., HAGUE INTERNATIONAL, SOUTH PORTLAND, MAINE

Mr. BJERKLIE. Good morning. Mr. Chairman, my name is John Bjerklie and I am manager of R. & D. for Hague International of South Portland, Maine.

It is my pleasure to be here to discuss alternative engines for automobiles and the role of NASA in their development. I have been fortunate over the last 3 years in being able to see first hand as a consulting engineer to the National Academy of Sciences the activities of a number of organizations engaged in developing alternative engines. Before that I was associated directly with the development of various specialized powerplants for use in aerospace. My observations on automobile engine development relate both to specific problem areas and to concept development. These are my private views, and not necessarily those of the National Academy of Sciences or any other organization.

Any engine suitable to the public must have low fuel consumption, be quiet, be safe, start easy, be driveable, be serviceable, have good tolerance to abuse and neglect and be low cost. To fit the low cost aspect the engine must also be easily designed for any power in the usable horsepower range, must be easy to control, must be easily produced, and must have a size and weight compatible with the vehicle.

Mr. GOLDWATER. I believe you have left out that they be low in pollutants.

Mr. BJERKLIE. It is taken for granted.

In addition, to be usable in the future it must be able to handle a multitude of fuels, or even different forms of stored energy. Also, with the need for clean urban air, urban vehicles must have low emissions. My consulting work on alternative engines has been to help evaluate their ability to meet these prerequisites.

The types of engines I have been concerned with have been unconventional in the sense that they are not now being produced for use in automobiles.

These include gas turbines, Rankine engines, Stirling engines, electric drives, flywheel drives and hybrids. In the past I have also studied diesel engines and stratified charge engines.

This list does not exhaust the possibilities for engine types but represents the major categories. Except for the latter two the heat engines are continuous combustion types and inherently have low exhaust emissions. The diesel and stratified charge engines, while inherently having lower emissions than conventional gasoline powered, spark ignition engines, need some exhaust clean up devices incorporated into the engine design. Battery and flywheel cars have basically the same emissions as the central powerplants from which their charging power comes.

Fuel consumption of these engines in comparison with gasoline powered, spark ignition engines vary considerably with the specific design, but appears to have potential as follows:

The Stirling engine is best.

Diesel engine, without emission controls.

High temperature gas turbines, running around 2,500° F.

Stratified charge engine, without emission controls.

Diesel engine, with controls.
Gasoline powered, spark ignition, without emission controls.
Stratified charge, with controls.
Gasoline engine, with controls.
Gas turbine, all metal.
Rankine engines, steam.
Rankine engines, organic fluid.

The differences between any engines adjacent on this list are small enough that the ranking could change depending on the exact configuration of the engine. The battery and flywheel powerplants can have better prima facie efficiency than any of those based on Btu equivalents, but useful energy consumption depends very much on weight penalties of the powerplants and on the efficiency of the central powerplant. None of these engines can be available in mass production before 1980, except for the diesel. An advanced diesel really suitable for automobiles as we know them in the United States will not be available before 1980 either. Prototypes of these engines are available, but prototypes which can be considered completely acceptable are not. Development time can vary considerably for some of the more advanced engines.

Testing for 50,000 miles and building in a reliability suitable for the general customer takes several more years of development beyond just coming up with a suitable prototype.

The major development problem for most of these alternative engine types is twofold:

1. Proving their suitability as automobile engines, as for Stirling, Rankine, flywheel, hybrids, and high performance battery powerplants; and

2. Ways of reducing cost while maintaining the desirable powerplant characteristics.

All the advanced powerplants, except flywheel, are being worked on to determine their suitability. Most of the engines, existing or advanced, have some characteristics which, if improved technically, could make them much more suitable for use in automobiles.

There is not enough such advanced development work going on, even for some of the presently accepted engines. Also, there is not enough work going on to bring along variations of major alternative types that could have improved characteristics over the basic form of the alternative.

I have listed in the written statement the R. & D. areas that would need work, if we are to get a reasonably well-rounded approach to a broad spectrum of alternative powerplants for automobiles and better ways to use them.

Work emphasis, based on probability of positive return, should be on combustion for all types of heat engines, ceramics for high-temperature gas turbines and Stirling engines, high-performance batteries, new energy sources other than fossil fuel conversion, and system studies of local and national transportation networks incorporating many types of vehicles and devices.

My personal opinion is that we should be working for something much broader than improved engines. We need to improve the whole energy-transportation-ecology situation.

We should aim to deliver anybody or anything in the United States to anyplace else in the country in a matter of 24 hours or so. We should

not congest cities. We should assist freedom of movement in urban areas. We should allow escape to rural areas when desired. We should not seriously contaminate urban air. We should not use up large fractions of the yearly production of critical metals. We should not cause the consumer any more capital outlay for transportation than he bears now. We should use no more than about one-quarter of the present per capita energy expenditure for all our transportation needs. Duplication of development efforts is desirable in that one man's failure may lead to another man's success. And we will need success.

This set of goals is not a dream, it is the logical result of using extentions of present-day technology. It is possible if development continues, if there is continued definition and study of the problem, and if there is information available for effective legislative and executive planning.

More than being a possible goal, some such goal as this is necessary if we are to maintain viable cities, breathable air, a thriving transportation system, and a vital energy system that can take care of a growing population emburdened with foreseeable and ever-succeeding crises upon crises.

The development of engines for ground transportation is obviously only a small part of an overall problem which promises to worsen. The real problem is one of improving the whole system of energy-transportation-ecology. The possible solutions will come in parts, and may not be fixed solutions for all locations.

We need to have a system that can nurture concepts and ideas all the way from the idea, through the embryo concept, to the acceptable prototype, and then to the marketable product.

Short-term goals imposed by both industry and Government preclude the nurturing of concepts that may be a little far out. Conservatism has to be the name of the game with the group. We need a group—or groups—that can look over new concepts with the eye of an entrepreneur and the vision of a futurist, if we are going to get the energy and transportation system we need that will serve the public maintain an improved ecology. We are generally missing in both industry and Government agencies the vision and entrepreneurship required. The capability for exploiting the unusual rests with many freethinking people acting with entrepreneural incentives.

Acceptability of an engine, or any concept, also follows particular patterns. The forces at work which determine whether a concept is right or not are fourfold: Technical acceptability, economic acceptability, political acceptability, and social acceptability.

A perfect technical solution accepted by the whole technical community is valueless if not subscribed to as an appropriate response by the economic and business community and by the public.

A perfect political solution in the eyes of both industry management and government managers and politicians is valueless unless it is subscribed to as an appropriate response by the economic and buisness community and by the public.

On the other hand, the economic and public are demanding groups. They are always at work and continually interacting. In ordinary everyday life there is no interaction with the technical and political communities—only with each other. This is true so long as we are dealing with a capitalistic society. However, when a problem arises and

there is a demand from one or the other group, the technical and political communities respond.

It is, therefore, clear that the interplay between political forces and technical forces—both of them responsive and not demanding forces—is inappropriate for introducing new concepts.

In short, the mode of satisfying the public should be settled in the arena of public and economic interplay—free enterprise. Policies and tools are the proper role of the political and technical communities in our society. This does not preclude their obligation to make their influence felt, however.

The appropriate use of creativity, wherever it may occur, is one of the best tools available.

A prime example of creativity in engine development with an entrepreneurial incentive to develop a salable product is the Carter family of Burkburnett, Tex. For a very small amount of their own money, costly with their own concepts, and in a relatively short time, they developed a steam engine to preprototype status, installed it in a car, and measured its mileage and emissions.

It was the first Rankine engine to demonstrate in a real driving cycle the ability to meet the 1977 emission standards. Its mileage was approximately 20 to 25 percent lower than the Volkswagen.

In my opinion, that steam engine is technically the best one of the recent spate of steam engines and other Rankine engines being developed with either private or Government funds. All the other development engines used much more money, at least a factor of 10 greater in all cases, and have not progressed so far so fast. Also, in my opinion, it promises to be the most economically viable of the Rankine engines being developed.

It is very expensive to go from the prototype through the acceptable prototype and then into production. Only big industry and the Government have the wherewithal. But the incentive exists only in industry to introduce a complete, new, profitable system that serves the needs of the general public.

Whatever transportation system evolves will undoubtedly maintain the auto as a major component, but the other components will have to serve as well as the auto does in its better aspects, if it is to be completely acceptable.

But the auto industry would like to hold status quo. It has to be urged by law to meet its social obligations as soon as such obligations look like a liability or unprofitable. And it has too short a planning time in many ways.

On the other hand, the Government, too, has short-term goals without adequate long-term planning—long term meaning more than 10 years, basically—and it ignores the entrepreneurial aspects of new concepts.

Neither the Government nor industry has a particularly good record on choosing for new development the most promising concepts suitable for long-term use. But they both have money with which engine development could be done. Also, the technical incentive exists in both bodies to do a good socially conscious engineering job on new engines; that is, technical incentive.

In the meantime, most concepts are killed off in both groups by low funding and strict critique at too early a stage. Who, then, is in a

position to nurture new concepts suitable for the future and still remain practical enough to satisfy industry?

Considering the technical needs for alternative engine development, the limitations of both Government and industry, the requirements for logical development of new concepts, and the manner of acceptance of new concepts, there is a logical role for NASA and similar Government organizations to—

1. Conduct R. & D. on the most costly elements of an overall program, making the findings available to everyone; and
2. Conduct system studies on overall energy-transportation-ecology considerations for urban and interurban travel, making the findings available to everyone.

Engine development, as such, should be left where the entrepreneurial incentive is—in the hands of industry, small business, and the inventor.

Whatever group does the complete job should be funded by both Government and industry, should be responsive to free enterprise incentives, should work under long-term planning, should be liberal in initial funding of promising concepts, should not be reluctant to duplicate effort, and should confer liberally with other social, political, economic, and technical groups having deep concern for the future.

In all probability, two or more competitive groups should be set up so that there is recourse for the prospective developer. It should serve as an information center as well as an embryo concept screening and funding center.

As such, it should staff itself to be aware of material resources use and availability. It should be able to investiagte alternative energy-transportation-ecology considerations as new concepts are proposed. It should investigate new engines, new means of transport, mixes of transport to meet urban needs and rural needs, and air, water, and land pollution. It should not be subject to overall scheduling, although task scheduling and goal setting are imperative. It should be reviewed by a mix of industry, government, institutional, small business, and public evaluators, with goals and leadership subject to change thereby.

While this may be too simplistic, I feel it absolutely necessary to have such a group, if we are to preserve for a long time our existing transportation benefits; such as, freedom of movement; freedom of choices on method, time, and destination of transport; ability to make profit from viable concepts; and the ability of our industry and Government to respond to local and general needs.

Other incentives properly placed may, also, do well for our Nation. Such incentives could take the form of subsidies or tax rebates to reward the user and/or manufacturer that cooperates with attempts to solve the critical air quality and urban congestion problems in stricken areas.

Likewise, it could be made to exact recompense from those who could do something about the problem and do not, these are the drivers of high emission cars in stricken areas; the producers of high emission vehicles; the producers of automotive fuels bearing sulfur, nitrogen, and high boiling ends; and the urban governments not instituting decongesting and low-emission transportation programs.

It is not unreasonable to ask that public transportation should offer all the advantages of autos—freedom of movement, convenience, low cost, relative privacy and protection, and as much prestige as de-

manded. Incorporation of Federal highway funding would possibly assure a more well-rounded program.

Subsidies that reward behavior which assists achievement of the social benefits of clean air and urban decongestion can bring about the large changes we need in our afflicted urban areas.

In summary, the requirements for achieving a viable energy-transportation-ecology system resolve down to only a few general needs:

1. Support R. & D. work in specific costly areas: Ceramics, combustion, new fuels, batteries;

2. Support study of overall energy-transportation-ecology systems to meet some overall national goals and goals for specific localities;

3. Support for initial development of embryo concepts regarding engines, fuels, and transportation; next,

4. Linkage of these supported technologies to economics, political, and social need for both national and local areas; and last,

5. Support of incentive programs in stricken areas for urging local clean air and decongestion.

It is hoped that it has been made clear that it is possible to do a much better job than we are doing, or that is envisioned in H.R. 10392, of improving our quality of life through a thorough approach to the problem. Thank you.

[The complete prepared statement of Mr. Bjerklie follows:]

Statement for hearings on HR 10392

by John W. Bjerklie, Manager
of R and D
Hague International
South Portland, Maine

It is my purpose here to discuss alternative engines for automobiles and the role of NASA in their development. I have been fortunate over the last three years in being able to see first hand as a consulting engineer to the National Academy of Sciences the activities of a number of organizations engaged in developing alternative engines. Before that I was associated directly with the development of various specialized power plants for use in aerospace. My observations on automobile engine development relate both to specific problem areas and to concept development. These are my private views, and not necessarily those of the National Academy of Sciences or any other organization.

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The types of engines I have been concerned with have been unconventional in the sense that they are not now being produced for use in automobiles. These include gas turbines, Rankine engines, Stirling engines, electric drives, flywheel drives, and hybrids. In the past I have also studied

diesel engines and stratified charge engines. This list does not exhaust the possibilities for engine types but represents the major categories. Except for the latter two the heat engines are continuous combustion types and inherently have low exhaust emissions. The diesel and stratified charge engines, while inherently having lower emissions than conventional gasoline powered, spark ignition engines, need some exhaust clean up devices incorporated into the engine design. Battery and flywheel cars have basically the same emissions as the central power plants from which their charging power comes.

Fuel consumption of these engines in comparison with gasoline powered spark ignition engines vary considerably with the specific design, but appears to have potential as follows:

Stirling engine - best
Diesel engine (without emission controls)
High temperature gas turbines
Stratified charge engine (without emission controls)
Diesel engine (with controls)
Gasoline powered spark ignition (without emission controls)
Stratified charge (with controls)
Gasoline engine (with controls)
Gas turbine (all metal)
Rankine engines - steam
Rankine engines - organic fluid

The differences between any engines adjacent on this list are small enough that the ranking could change depending on the exact configuration of the engine. The battery and flywheel power plants can have better prima-facie efficiency than any of those based on BTU equivalents, but useful energy consumption depends very much on weight penalties of the

power plants and on the effiency of the central power plant. For the future the efficiency comparisons concerning any of these engines will be better made on an energy cost basis rather than a BTU basis. As of now the heat engine fuel costs are less than for the electrically charged vehicles. For now the heat engine ranking remains essentially the same whether considering BTU or cost.

The elapsed time before any of these power plants could be introduced to the public extends well into the 1980's. Engines of particular types can be built now to operate in cars. In fact there are cars now operating with all of these power plants except for organic Rankine and flywheel types. Buses with these two kinds of power plants have been operated, however. This does not imply that these prototypes are suitable for use in the American automobile as we have known it.

A typical time span for developing a suitable prototype engine varies from about a year for an uncontrolled spark ignition engine to several decades for the advanced engines. On a crash basis we could expect that gas turbines or Stirling engines would take as much as four years to be developed into a suitable prototype engine starting from today's technology. Rankine engines would be either shorter or longer, depending on which type is being considered. Suitable prototype battery cars could be developed in a few years using existing battery technology, but would not be very competitive vehicles. High performance batteries may be a decade, or so, away even with lots of development. Diesel engines also need considerable development time if they are to be made significantly lighter, cleaner, and less costly than they are now. Stratified charge engines are relatively short term development engines for some types, but can also extend into years for other types.

Once a suitable prototype is reached, the proof testing and tooling can extend over another six to ten years before significant production is reached.

The major development problem for most of these alternative engine types is twofold:

1) proving their suitability as automobile engines, as for Stirling, Rankine, flywheel, hybrids, and high performance battery power plants, and
2) ways of reducing cost while maintaining the desirable power plant characteristics.

All the advanced power plants, except flywheel, are being worked on to determine their suitability. Most of the engines, existing or advanced, have some characteristics which, if improved technically, could make them much more suitable for use in automobiles. There is not enough such advanced development work going on, even for some of the presently accepted engines. Also, there is not enough work going on to bring along variations of major alternative types that could have improved characteristics over the basic form of the alternative.

The R and D areas that are needed for furthering the development of a broad spectrum of power plants suitable for automobiles are tabulated at the end of this statement.

Work emphasis, based on probability of positive return, should be on combustion for all types of heat engines, ceramics for high temperature gas turbines and Stirling engines, high performance batteries, new energy sources other than fossil fuel conversion, and system studies of local and national transportation networks incorporating many types of vehicles and devices.

Some aspects of these R and D areas are now being worked on by government agencies and in industry, but none of them are being worked on to the degree necessary to produce either a viable alternative engine in the next 20 years, or an improved overall transportation system, or a

long lasting solution to the energy problem. All these aspects must be faced if the American, and the world's, people are to see an improving energy-transportation-ecology situation. A suitable range of solutions and alternatives must be available for rapid institution so that in ten to twenty years from now we can be on track toward a high performance transportation system. This system should be able to deliver anybody or anything in the United States to anyplace else in the country in a matter of 24 hours, or so. It should not congest cities. It should assist freedom of movement in urban areas. It should allow escape to rural areas when desired. It should not seriously contaminate urban air. It should not use up large fractions of the yearly production of critical metals. It should not cause the consumer any more capital outlay for transportation than he bears now. It should use no more than about one quarter of the present per capita energy expenditure for all our transportation needs. Duplication of development efforts may be desirable in that ones man's failure may lead to another man's success - and we will need success.

This set of goals is not a dream, it is the logical result of using extensions of present day technology. It is possible if development continues, if there is continued definition and study of the problem, and if there is information available for effective legislative and executive planning. More than being a possible goal, some such goal as this is necessary if we are to maintain viable cities, breathable air, a thriving transportation system, and a vital energy system that can take care of a growing population emburdened with foreseeable and ever succeeding crises upon crises. We can avert most of these crises by providing the basis for recovery before they begin. If we don't, there will one day be a crisis we cannot cope with in time to prevent the mass of humanity from plunging to the edge of misery. Massive breakdown of our way of life is

a distinct possibility if information and communication on viable alternatives to existing technology and societal foundations are not available in times of crisis.

The development of engines for ground transportation is obviously only a small part of an overall problem which promises to worsen. The real problem is one of improving the whole system of energy-transportation-ecology. The possible solutions will come in parts, and may not be fixed solutions for all locations. Origination of potential solutions, their development, and their institution are the problems that relate to the role of various groups in this overall endeavor.

NASA has in the past worked on critical problems of airplanes and engines, and admirably assisted the aircraft industry when it was NACA. Some of the NACA'S high technology areas were maintained and others were allowed to diminish in capability when it became NASA and tackled the space program. Emphasis was placed on management of programs for a well defined goal. Ground transportation problems involve the overall system, which NASA should be able to study; it involves high technology for general use by engine companies, to which NASA in the past has been able to contribute; and it involves engine and vehicle development, which NASA has done only on a management basis for a particular type problem. The overall system studies are not now being done well by industry, the general technology work is being done in part by industry, and the engine and vehicle work is being done well by industry on a competitive basis - particularly with regard to cars and trucks. The type of work being done on the part of NASA and industry is clear - NASA does well where it doesn't compete, and industry does well where it does compete. The logical extension of this concept is that NASA should only be involved in high technology

involving engine and vehicle components and in the study of overall systems problems. Industry, by the same token, should continue with the competitive development of complete engines and vehicles.

The way in which development occurs, selection of acceptable concepts, their method of selection for development and for introduction to the market, and the limitations of the development groups are all important to clarifying the role of NASA-like organizations and industry. Such considerations also suggest improved methods of handling the problem of developing new engine and transportations concepts.

A typical development program goes something as follows. Whenever a new problem arises, myriad solutions are concepted, but are quickly narrowed down. This process is inexpensive. Decisions are then made as to which concepts should be carried on. The critical time for a concept is after initial evaluation and before such decisions. It is extremely easy to kill a good concept at this time by being too cursory with it or too demanding of it before it is investigated sufficiently. It is at this time that concept review by people with vision is required and when an entrepreneurial insight is extremely valuable.

Selected concepts are developed to fit the technical problem best and at the same time match the natural evolution of the existing system into which they must fit. This is the expensive part of development programs. Because of the large expense the choice programs are usually conservative. They eventually are fitted to the requirements at hand and are readied for the market. The market then sorts out the most viable concept.

We are generally missing in both big industry and government agencies the vision and entrepreneurship required to bring along the most commercially promising concepts that are somewhat out of the ordinary. The capability for exploiting the unusual rests with many free thinking people acting

with entrepreneurial incentives.

Acceptability of an engine, or any concept, also follows particular patterns. The forces at work which determine whether a concept is right or not are fourfold - technical acceptability, economic acceptability, political acceptability, and social acceptability. Technical acceptability of a product is measured by its ability to perform,its characteristics in use, its manufacturability, and its cost. Normally a technical effort to develop acceptable concepts follows demands set up either economicaly or socially. It is a response. A perfect technical solution accepted by the whole technical community is valueless if not subscribed to as an appropriate response by the economic and business community and by the public. The SST is a good example of an unacceptable good technical concept.

Likewise, political motivation toward a particular solution is not enough. It, too, is normally a response that must be tempered by the other forces. A perfect political solution in the eyes of both industry management and government managers and politicians is valueless unless it is subscribed to as an appropriate response by the economic and business community and by the public. The difficulties in motivating industry and the public following the clean air act is a good example of this.

On the other hand, the economic and public are demanding groups. They are always at work and continually interacting. In ordinary everyday life there is no interaction with the technical and political communities - only with each other. This is true so long as we are dealing with a capitalistic society. However, when a problem arises and there is a demand from one or the other group the technical and political communities respond.

It is, therefore, clear that the interplay between political forces and technical forces - both of them responsive, and not demanding forces - is inappropriate for introducing new concepts.

An indication of the difficulties is seen in the space program itself -

a marriage of political and technical communities to accomplish a given end. It certainly interested the public at first, but it was not missed greatly when its effort was reduced. It interested the economic community to the extent that profit could be made on the expenditures, but economic fall out in terms of new products was too little to spur the economy except in local areas. The feeling of unacceptance has extended into the competitive technical world responding to normal public and economic demands to the extent that a qualified man trained in the aerospace industry has a difficult time finding a position or feeling comfortable in the normal technical world. It may take years before an aerospace man can contribute as he should in the competitive technical world.

In short, the mode of satisfying the public should be settled in the arena of public and economic interplay - free enterprise. Policies and tools are the proper role of the political and technical communities in our society. This does not preclude their obligation to make their influence felt, however.

The pattern of how concepts originate is as important to recognize as the pattern of development and acceptability. These patterns may make clear where we can expect to find needed concepts.

The concept itself, irrespective of its acceptability, can originate anywhere in the technical-economic-political-social circuit. New engine concepts are usually introduced in the technical community, albeit Robert Stirling, the inventor of the Stirling engine, was a minister. The technical community is a complex system wherein engineers and scientists collectively work in many different environments.

Technical men vary in the quantity and quality of their creativity. By and large, a creative man in one environment will also be creative in another. But a creative person depending on development of saleable products for

continuing his employment will have the incentive to screen out concepts that will not lead to publicly acceptable products, or that won't yield to reasonably rapid development and competitive price, even though such concepts may be interesting. On the other hand, a creative person depending on creating technically interesting results in return for continuation of employment will have incentive to dig ever deeper and to more thoroughly understand his technical problem. This sometimes precludes his ability to make decisions appropriate to rapid development of a concept. Also, a creative person who is of such a stature that he need not worry about continuation of employment will follow his head into interesting areas that may do the public some good as opposed to simply satisfying his boss. This last category is not very numerous. It is fortunate in our society that we can use these three types of creative people. However, the three types thrive best in different environments.

A prime example of creativity in engine development with an entrepreneurial incentive to develop a saleable product is the Carter family of Burkburnett, Texas. For a very small amount of their own money, mostly with their own concepts, and in a relatively short time, they developed a steam engine to pre-prototype status, installed it in a car, and measured its mileage and emissions. It was the first Rankine engine to demonstrate in a real driving cycle the ability to meet the 1977 emission standards. In my opinion, that steam engine is technically the best one of the recent spate of steam engines and other Rankine engines being developed with either private or government funds. All the other development engines used much more money (at least a factor of 10 greater in all cases) and have not progressed so far so fast. Also, in my opinion, it promises to be the most economically viable of the Rankine engines being developed. Whereas I think steam engines will have a limited market, this is still an excellent

example showing several things:

1) good brains are not concentrated in any particular location, agency, or company;
2) entrepreneurial bravery is still rampant in this country, and
3) with proper incentive, a commercially oriented, technical product can be developed in a timely and economic fashion.

This type of activity should .. encouraged, but it is the kind usually killed off in the critical stages of developing an embryo concept. Whether the Carter steam engine, or any engine, ever sees the light of day as part of a product for sale in a showroom depends on how much funding is available at the embryo state and on i..to product development. The later stages of engine development to the point of introduction to the mass public is extremely expensive. The huge expenses of engine development is incurred in large part by having to build in its reliability before introduction to the public. Tooling is another large part of the expense. It is fair to say that only a few industries in the country can tackle it. The public is the only source of sufficient funds to do the whole job - their money being collected in large pools in the form of taxes by the government and through profits by private enterprise. The auto industry and the U. S. government are the two agencies that can collect the public's money in big enough pools to do massive engine development. Thus, th. .e are the only agencies with the concentrated wherewithal for a complete change in engines or for an entirely reformed transportation systems. Only the auto industry has the economic incentive to cause the changes. On the other hand, we have seen that the auto industry attempts to hold the status quo, and its development toward clean engines has been the result of the government persisting in enforcement activities of the clean air act and attempting to improve urban life.

The incentives of both government and big industry is suspect when it comes to development of new and advanced concepts. Neither has demonstrated motivation toward the long-term public good in technological areas. Both the government and the auto industry have to limit themselves to short-term goals - industry because it has to make a profit for its shareholders, and government because of its year-to-year budgeting in a climate that calls for satisfying the voters every few years. On the other hand, large industry can, if required, put up large sums for periods of several years to overcome a problem. The emissions problem has emphasized its capability of doing this. It also emphasizes the fact that the status quo on engines would have been held if the government had not stepped in; that is, engines would have remained unclean unless it had turned profitable to make them clean.

It has become clear that government funded science and engineering programs are subject to yearly variation as to funding and goals. We have seen science and engineering programs diminish in funding and seriously change goals on a year-to-year basis. These changes have been far from universally approved by the academic and technical communities. So the government is an unreliable source of large sums of money for long periods unless national defense is at issue.

Moreover, neither government nor industry has been particularly clairvoyant on deciding which concepts to back in various situations, and as a consequence most good concepts go begging for years. Then, in a few cases, tenacity has finally paid off for the technical entrepreneur. Even in instances of apparent insight sufficient to sponsor potentially viable alternative engines, the effort is crippled by the imposition of extremely tight schedules that preclude creative development.

The situation, then, for the auto industry and the government is a set-up which on the government side -

- ignores the entrepreneurial aspects of technical tasks
- has short range funding and short-range goals
- has not demonstrated its ability to recognize technical merit in the embryo stage,

and on the side of the auto industry, it

- has short-range goals, but could make available low level, long-term funding
- has incentive to ward off new concepts
- requires legal urging to meet some of its social commitments.

On the other hand, they both have money with which engine development could be done. Also, the technical incentive exists in both bodies to do a good, socially conscious, engineering job on new engines. In the meantime, most concepts are killed off in both groups by low funding and strict critique at too early a stage. Who, then, is in position to nurture new concepts suitable for the future and still remain practical enough to satisfy industry?

Considering the technical needs for alternative engine development, the limitations of both government and industry, the requirements for logical development of new concepts, and the manner of acceptance of new concepts there is a logical role for NASA and similar government organizations:

1) conduct R and D on the most costly elements of an overall program, making the findings available to everyone,
2) conduct system studies on overall energy-transportation-ecology considerations for urban and interurban travel, making the findings available to everyone.

Engine development, as such, should be left where the entrepreneurial incentive is - in the hands of industry, small business, and the inventor.

NASA could provide critical technical tools for these people.

A more suitable organization to cover the whole problem would also include the task of screening new concepts and funding the more promising ones past the embryo stage. It would be necessary to work out patent rights clauses that allow the recipient to retain all the rights possible without impeding the public's access to the benefits. It would be necessary to man such a group with entrepreneurially inclined persons having a good vision of future needs as well as present needs. This kind of group would have to be originated anew, since none exists now.

Whatever group does the complete job, if it's ever to be done that way, should be funded by both government and industry, should be responsive to free enterprise incentives, should work under long-term planning, should be liberal in initial funding of promising concepts, should not be reluctant to duplicate effort, and should confer liberally with other social, political, economic and technical groups having deep concern for the future. In all probability, two or more competitive groups should be set up so that there is recourse for the prospective developer. It should serve as an information center as well as an embryo concept screening and funding center. As such it should staff itself to be aware of material resources use and availability. It should be able to investigate alternative energy-transportation-ecology considerations as new concepts are proposed. It should investigate new engines, new means of transport, mixes of transport to meet urban needs and rural needs, and air, water, and land pollution. It should not be subject to overall scheduling although task scheduling and goal setting are imperative. It should be reviewed by a mix of industry, government, institutional, small business, and public evaluators, with goals and leadership subject to change thereby.

Such a group, while possibly idyllic, I feel to be absolutely necessary if we are to preserve for a long time our existing transportation benefits: freedom of movement, freedom of choices on method, time and destination of transport, ability to make profit from viable concepts, and the ability of our industry and government to respond to local and general needs.

Other incentives properly placed may, also, do well for our nation. Such incentives could take the form of subsidies or tax rebates to reward the user and/or manufacturer that cooperates with attempts to solve the critical air quality and urban congestion problems in stricken areas. Likewise, it could be made to exact recompense from those who could do something about the problem and do not - the drivers of high emission cars in stricken areas, the producers of high emission vehicles, the producers of automotive fuels bearing sulfur, nitrogen, and high boilig ends, and the urban governments not instituting decongesting and low-emission transportation programs. It is not unreasonable to ask that public transportation should offer all the advantages of autos - freedom of movement, convenience, low cost, relative privacy and protection, and as much prestige as demanded. Incorporation of federal highway funding would possibly assure a more well rounded program.

Once technological concepts are brought to the point of being nearly competitive, and if they have a clear social benefit, subsidies and tax benefits could push the economics in the direction of greatest social benefit. This, of course, is what has already been done many times over in the transportation business - railroads with their large land grants in the 19th century, the auto/highway system with public road building, and the airways through airport construction and FAA operations.

Subsidies that reward behavior which assists achievement of the social benefits of clean air and urban decongestion can bring about the large changes we need in our afflicted urban areas.

In summary, the requirements for achieving a viable energy-transportation-ecology system resolve down to only a few general needs:

- support R & D work in specific costly areas - ceramics, combustion, new fuels, batteries;
- support study of overall energy-transportation-ecology systems to meet some overall national goals and goals for specific localities;
- support for initial development of embryo concepts regarding engines, fuels,and transportation;
- linkage of these supported technologies to economics, political and social need for both national and local areas;
- support of incentive programs in stricken areas for urging local clean air and decongestion.

NASA could be of help on some of this, but a more entrepreneurially oriented group is required to do the complete job. A broad outlook on the part of governing bodies is required if best advantage of all the potentials is to be made.

It is hoped that it has been made clear that it is possible to do a much better job than we are doing, or that is envisioned in H. R. 10392, of improving our quality of life through a thorough approach to the problem.

APPENDIX

R & D areas needed for furthering the development of a broad spectrum of power plants suitable for automobiles:

1) High strength, high temperature ceramics for use in gas turbine combustors, turbines, nozzle rings, and regenerators.
2) High strength, high temperature, highly thermal conductive ceramics, and high strength, high temperature, highly thermal resistive ceramics for use in Stirling engine heater heads, displacer piston domes, cylinder and regenerator housings, or preheaters.
3) Economical methods of fabricating such ceramics.
4) Hydrogen diffusion inhibitor usable at 1500°F for use in closed loop power plants.
5) Rotary positive displacement mechanisms of low leakage and long life in 1500°F environment with hydrogen working fluids.
6) A simplified power control system suitable for use with Stirling engines.
7) An inexpensive and reliable infinitely variable transmission suitable for use on single spool automobile gas turbine.
8) Suitable seals to be used with gas turbine regenerators, or alternatively, a suitable effective and reliable high temperature recuperators.
9) A mass producible boiler for use with steam engines.
10) A high temperature, low loss valving system for use with reciprocating Brayton engines.
11) The demonstration of working models of new forms of alternative engines.
12) The demonstration of a low cost flywheel drive system in conjunction with an infinitely variable transmission.

13) Fundamental combustion studies with distillate fuel oils to show potential for very low emissions and low excess air as necessary for gas turbine, Stirling engine, and Renking engine combustors.
14) Fundamental combustion studies for diesel, stratified charge, and carbureted spark ignition engines using distillate fuels to show potential for very low emissions and low excess air as necessary.
15) Applied combustion studies with modified combustor configurations demonstrating capabilities of as low emissions as possible in carbureted spark ignition engines, diesel engine, stratified charge engines, gas turbines, Stirling engines, and steam engines.
16) Development and demonstration of an inexpensive electric drive system.
17) High energy density batteries suitable for long life with deep cycling.
18) Fuel modifications that can lead to low emission combustion.
19) Investigation of fuel sources other than petroleum - and not limited to conversion of coal, shale oil, tar sands, vegetation, and waste for use as transportable energy similar to gasoline.
20) Study of alternative ways to use existing technology and various transportation mixes for use of self-powered vehicles for improving urban costs and national costs while achieving improved personal transportation in urban and rural areas.

Mr. SYMINGTON. Dr. Bjerklie, that is a splendid presentation. We are heartened by what I deem to be your general support of the thrust of the bill.

Are you thoroughly familiar with the bill or just its broad outlines?

Mr. BJERKLIE. Just its broad outlines.

Mr. SYMINGTON. With a paper like this, if you found anything wrong with the bill, I would like to know what that is, too.

Mr. BJERKLIE. I have not read the bill in detail.

Mr. SYMINGTON. The auto industry is somewhat divided, I think, which is an interesting phenomenon in and of itself, on its approach to the bill. One company thought that giving NASA this responsibility was just a plain good idea, and another feared that it would open up another agency for them to deal with in matters of this kind, and it would diffuse the Federal responsibility for assisting or working with or coordinating the industry's effort to meet emission control needs, fuel economy requirements, et cetera, as well as the workings of a good engine itself.

They felt they had to deal with DOT and EPA and maybe one or two other agencies, and they felt NASA was just another level of bureaucracy for them to deal with. The third company was somewhat neutral on the point. But each of them felt that some kind of Federal effort was warranted, that the industry in its desperate effort to keep up with the demands of today, the emission control requirements of 1975 and 1977, and so on, were dedicating a rather large portion of their R. & D. effort to putting out these current fires and were not really able to address themselves to the future, although they were looking at the engines you mentioned here on page 2.

Some of them seemed to feel they were already in a position to reject certain approaches.

To what extent are you familiar with what the industry is doing?

Mr. BJERKLIE. As a consultant to the Committee on Motor Vehicle Emissions of the National Academy of Sciences, for the last 3 years I have visited the Big Three and a number of the other companies in the United States concerning engine development of alternative engines which originally included diesel engines, and in the last round of visits included only the gas turbine, the Stirling engine, the Rankine engines, the electrics, and to a very small degree flywheels.

I have visited in Europe as well as the United States.

Mr. SYMINGTON. Without trying to make odious comparisons or contrasts—you have been to the Big Three, and have you been to American Motors besides?

Mr. BJERKLIE. I have not been to American Motors, just the Big Three.

Mr. SYMINGTON. By the way, why do we constantly ignore American Motors?

Mr. BJERKLIE. American Motors has made it reasonably clear to the National Academy of Sciences—among others, I presume—that they will essentially buy their emission technology from others—I believe GM primarily.

Mr. SYMINGTON. Their emission technology; but you do not know what they are doing with respect to automotive engineering?

Mr. BJERKLIE. When I contacted the people at American Motors 2 years ago, they essentially said they are doing no work in alternative engines.

Mr. SYMINGTON. No work?

Mr. BJERKLIE. No work.

Mr. SYMINGTON. Did it occur to you to ask why that was, or did it occur to them to elucidate further?

Mr. BJERKLIE. It occurred to me to ask. I did not feel it was quite my place, since they did not choose to tell me. I guess I made the arbitrary assumption that being the smallest of the four major manufacturers and having stated that they would essentially but their emission controls——

Mr. SYMINGTON. I was just trying to get hold of what you deemed your role to be in these matters.

I'm sorry to interrupt this line, but I have to make a call at this moment. I would ask Mr. Brown to take over the chair. I will be right back.

Mr. BROWN. While he is gone, I might volunteer an answer to that question myself. It is essentially what I think you are getting at, and that is that up until the last year, American Motors has been the least profitable of them.

Mr. BJERKLIE. I believe that is correct.

Mr. BROWN. It takes a certain amount of profit in order to maintain any degree of research and development activity which is generally the first thing to be dispensed with when you don't happen to have it.

I was very much impressed by your presentation, Dr. Bjerklie, and particularly—this, of course, is merely because it appeals to my own thinking—your emphasis on achieving a viable enery-transportation-ecology system. Obviously, this piece of legislation and any legislation I know of which has been before the Congress would fail to address itself to all of the problems involved in that. It is one of the more frustrating things about being in Congress.

I hope you get elected some time so you can share that frustration. [Laughter.]

The mechanisms within the Congress for addressing system problems are very weak. And this bill is, I think, a reflection of that. Not to detract from its merit, because I think it is a very good bill, but it does not address the whole problem which you attempt to address in your statement. I appreciate that.

The particular thing I am interested in, of course, is defining the area in which NASA could play a role in connection with the solution of—if not the whole energy and transportation technology problem—at least that part having to do with developing alternative engine systems. And you have in your appendix and also in your statement listed a number of areas which need further development.

It appears to me by just a casual examination that these are the kinds of things where NASA has a high competence and in many cases is already doing some work in the area. I think ceramics is an example. And certainly they are working in the area of hydrogen.

They have done considerable research there. I am wondering if you would comment as to whether in your view these are tasks which could be appropriately conducted by NASA either in-house or under contract.

Mr. BJERKLIE. I think there are some aspects here which certainly could be attacked by NASA as it exists. There are probably more which could be attacked by NACA as it was originally constituted before it turned into NASA.

NACA had a very good combustion group for instance. The work they were doing could logically extend now, even now, to the combustion work for low emissions which is still necessary. The gas turbine combustor, for instance, has demonstrated high NO_x compared to the lowest NO_x which is required.

I believe it can be reduced based upon some of the work our own company has done. I think I can say that some of the concepts which are available in combustion for other applications could be extended to reduce the emissions in gas turbines even more than they have been reduced. Gas turbines are quite low already, but they do not meet the NO_x requirements in any projected automotive gas turbine engine.

So there is one example where NASA, if it reinstituted its combustion groups essentially as they were when it was NACA, and kept some of its present combustion capability, such as at JPL, and married the two types of approaches, I think that NASA could contribute very well.

Ceramics work is very expensive and very frustrating and very difficult. I think the ARPA contract with Westinghouse and Ford is a good step forward. I think there is room for lots more work. I think in fact high temperature ceramics would be necessary in order to make the high temperature gas turbine a reality.

And with the high temperature gas turbine you can start talking about a competitive engine. Again, I repeat that would be 2,500 degrees turbine inlet temperature or thereabouts, whereas the gas turbine with only a ceramic regenerator is limited to roughly 1,900 to 2,000 degrees Fahrenheit and is not competitive in many ways, sizewise, costwise, and performancewise.

Mr. BROWN. There are similar problems in connection with the steam engine, if I correctly understand it, in that the components presently used are incapable of operating at the temperatures and pressures which would be required to increase its obviously low efficiency.

Mr. BJERKLIE. I think the steam engine is another kind of beast. It is probably of the alternative engines, of the far advanced alternative engines, let's say of the external combustion or continuous combustion types, the easiest to make.

However, it is still a difficult engine for development and prototype programs. But it does not have as far to grow. It is not ever going to be an engine which can compete in performance with, say, even a high-temperature gas turbine or a Stirling engine. The potential for the steam engine is close to being developed already in my own opinion.

I referred to the Carter family which is essentially a father and son in Texas. They have worked on a small steam engine. In a previous report which our group wrote for the National Academy of Sciences about a year ago, "An Evaluation of Alternative Power Sources for Low Emission Automobiles," we referred to Rankine engines and advanced Rankine engines, and the advanced Rankine engine, as indicated in there, was close to what we thought would be the best possible you could do with a Rankine engine.

It fell far short of many of the others. I believe the Carter engine is close to what we called the advanced Rankine engine at that time.

I guess what I am getting around to saying is that I do not know that any amount of improvement by anybody is going to convert the Rankine engine, steam engine or organic, to the really good com-

petitive engine it has to be in order to be incorporated into the American automobile system.

Mr. BROWN. I appreciate that comment, since some of my friends in California are involved in trying to develop the steam engine to be competitive. They give me a very rosy view of it which you have helped to offset a little bit.

Mr. BJERKLIE. It is sort of like, I guess, back in World War II you could develop a fighter plane up to its limit and then you had to start on a whole new generation in order to get improvements beyond that.

It is a similar situation. We have a steam engine which can be developed. It can be made a good engine, but similar development on a more advanced engine would give you more in the end.

Mr. BROWN. The point I was trying to make is that the NASA capability for engaging in materials research in areas involving high temperature and pressure presumably would be useful in connection with a number of types of engine developments which we might anticipate.

I think one of the aspects of the wording of the bill before us which pulsion systems."

Now this may have been construed as actually manufacturing engines, which is not the purpose of the legislation. Perhaps that phrase will need to be redrafted in order to more specifically indicate the areas which you and others have indicated are directly pertinent to the expertise which NASA has.

I have no further questions, Mr. Chairman.

Mr. SYMINGTON. In your visits to the Big Three automakers you became, would you say, thoroughly familiar with what each of them is doing on alternative engine research?

Mr. BJERKLIE. Visiting the Big Three is an experience that I think you have to actually experience in order to appreciate. But if you ask the right questions, you can get all the information which can be given readily.

It is very difficult to ask the right questions sometimes. We hope that we have asked mostly the right questions. We have gotten answers very frankly in most cases. We have found on looking back after such visits that at least in the case of one company we were not given total information.

I cannot make the same comment with regard to the other two.

Mr. SYMINGTON. Are you doing a report on those visits? Are those recent visits?

Mr. BJERKLIE. I am presently preparing a final report for the National Academy of Sciences.

Mr. SYMINGTON. We ask questions from every conceivable direction as they occur to us, but one thing we tend to ask is: "How much of your total R. & D. budget is devoted to this?" It is not that you can actually learn all that much about the level of effort, but you get some kind of idea of the importance they attach to this kind of R. & D. and, of course, the nature of it and how many people are working on it.

Do you ask those questions yourself?

Mr. BJERKLIE. Yes.

Mr. SYMINGTON. So that kind of thing will appear in your report?

Mr. BJERKLIE. It will be indicated. Some answers are given in confidence and we would like to respect those confidences.

Mr. SYMINGTON. And can you get an idea, when you are talking to them, of the distance down the road they are looking in the kind of research they are doing? In other words, it would almost be interesting and useful to have a chart showing the level of expenditure and effort and personnel involved in preparing what they think might be the 1980 engine, the 1990 engine and beyond, as distinct from just going along.

Or are they really thinking about target dates for operational capability of various engines, or are they still in very basic research?

Mr. BJERKLIE. I think they are thinking about possible introduction dates for various engines based upon what we have been told. However, they are not willing—and nobody should be willing at this point to say that the Stirling engine or the gas turbine engine will be it. So, therefore, they cannot state dates which really mean very much. It is still a matter of wait and see. All you can judge from is, as you suggested, the intensity of their effort.

Mr. SYMINGTON. Are they thinking in terms of alternative fuels, all of the reasonably potential alternative fuels, such as steam?

Mr. BJERKLIE. Steam is not an alternative fuel.

Mr. SYMINGTON. How do they produce steam.

Mr. BJERKLIE. Of course, you have an external combustion system with the steam engine or Stirling engine.

Mr. SYMINGTON. Would you need old fashioned fossil fuels for that?

Mr. BJERKLIE. Anything from cow dung to wood chips along with hydrogen or methanol. Now that is in two cases, the Stirling engine and the Rankine engine.

In the gas engine you have again a wide variety of potential fuels you can use, but basically they will be fluid or liquid, something which could be handled in that way.

Yes, there is consideration in the auto industry for alternative fuels, if we talk liquid fuels. And the degree to which they are considered varies from group to group within the companies.

Those who are interested in auto engines as we presently know them, are more interested in gasoline, modifications and additives such as methanol, et cetera. And those who are concerned with gas turbines and Stirling cycles and steam engines do look at and try to keep track of the various fuels they could be using, their availability and cost.

Mr. SYMINGTON. Do you also visit the Department of Transportation and find out what their input is in all of this research?

Mr. BJERKLIE. If not visits as such, we attend some of their briefings, yes.

Mr. SYMINGTON. They told us they were not really into R. & D. very deeply. They said it is up to Detroit to do it.

Mr. BJERKLIE. Basically it is correct. They do systems studies which I think are very valuable. I think, as I pointed out, without systems studies for each individual local area and possibly for the whole country in some aspects that any amount of engine work will probably not do us any good.

Mr. SYMINGTON. When you say basically that is correct, that does not take away from your original support for the idea of NASA-sponsored analysis of these things and R. & D. on its own?

Mr. BJERKLIE. I kind of lump all of those as Government, being naive. I can say that the Government in one form or another probably

is the only group which can do such long-term studies of systems at this moment. My personal preference, of course, would be for this work to be done by something possibly nonprofit and not in Government or industry, more like NASA or some advanced version of Battelle or something like that which is responsive to incentive concepts and responsive to the needs of industry as well as responsive to the needs of the public.

Mr. SYMINGTON. I want to thank you very much for your testimony and the care you took in preparing it.

Mr. BJERKLIE. My pleasure.

Mr. SYMINGTON. The subcommittee will meet again next Tuesday at 10 o'clock in this room. Today's meeting is adjourned.

[Whereupon, at 11:55 a.m., the subcommittee was adjourned to reconvene on Tuesday, June 18, 1974.]

RESEARCH ON GROUND PROPULSION SYSTEMS

TUESDAY, JUNE 18, 1974

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to adjournment, in room 2325, Rayburn House Office Building, Hon. George E. Brown, presiding.

Mr. BROWN. The subcommittee will be in order.

Chairman Symington is on his way, and will be here shortly. Because we have a number of witnesses, I thought we should get started in order to conserve time.

Today, we are holding the fourth and final meeting in the current set of hearings on H.R. 10392, a bill to authorize NASA to conduct research on ground propulsion systems.

In our first set of hearings last February, the subcommittee heard the testimony of witnesses from Government agencies responsible for this type of research. In the current set of hearings, witnesses have represented the private sector—the automotive industry, independent developers, consultants, and other interested parties.

This morning, our leadoff witness is Mr. Sam B. Williams, president of Williams Research Corp. of Walled Lake, Mich., a company engaged in automobile engine research for the past 20 years. Prior to the formation of his own company in 1954, Mr. Williams was employed by Chrysler Corp.

I would also like to welcome our chairman, Mr. Symington, who will now take over.

Mr. SYMINGTON. Thank you, Mr. Brown. We have votes in the Commerce Committee this morning and I may be interrupted from time to time.

I am here to welcome you, Mr. Williams, and you may proceed with your prepared statement.

Mr. WILLIAMS. Thank you, Mr. Chairman.

I would first like to mention my corporation is located near Detroit. We employ a little over 500 people. They are all engaged in manufacturing and development work on gas turbine engines. These engines are aircraft turbo engines and auxiliary power units and automobile gas turbine engines. They are all in the basic size range of the automotive type engines components all about the same size.

I'd like to introduce Mr. David C. Jolivette who is our vice president of public relations. Mr. Jolivette will read our statement, and then I would be pleased to answer questions.

Mr. SYMINGTON. Very good.

[A biographical sketch of Mr. Williams follows:]

SAM B. WILLIAMS

Mr. Sam B. Williams is Chairman of the Board and President of Williams Research Corporation of Walled Lake, Michigan, near Detroit. He has managed this company since its formation in 1954, from its early successes as a turbine engine development company, through its rapid expansion, to its current status as the world's leading manufacturer of small jet engines.

Mr. Williams continues to play an active role in his corporation's technical program, including the development of low emissions and low consumption automotive gas turbine engines, small turbojet and fanjet engines, and turbine engines that provide secondary power retirements for large aircraft.

Prior to forming his own organization, Mr. Williams was in charge of the design of the first Chrysler automotive gas turbine engine and played a key role in the design of one of the first aircraft turboprop engines developed for the U.S. Navy.

Mr. Williams is internationally recognized as a leader in the automotive, industrial and aircraft gas turbine fields. He holds numerous patents in turbine engine design.

Through its advancements of small gas turbines, Williams Research has become the technology leader in its field and the world's largest producer of miniature jet engines of less than 1,000 pounds of thrust.

Mr. Williams is a graduate of Purdue University and is a member of the Society of Automotive Engineers, American Society of Mechanical Engineers, American Ordnance Association, Association of the United States Army, American Institute of Aeronautics and Astronautics and the American Helicopter Society.

STATEMENT OF SAM B. WILLIAMS, PRESIDENT, AND DAVID C. JOLIVETTE, VICE PRESIDENT OF PUBLIC RELATIONS, WILLIAMS RESEARCH CORP.

Mr. JOLIVETTE. Mr. Chairman and members of the subcommittee.

I appreciate the opportunity of being a part of these hearings on bill H.R. 10392. I would like to express my views as to the proper Government role in the development of alternate powerplants, as well as my views with respect to the future potential of the automotive gas turbine engine.

In considering the Government's proper role in influencing and assisting the automotive industry in reducing annual energy consumption, I believe it is important to review the past actions and results with respect to air pollution. The result of this past Government action has certainly been cleaner air, which we all desire and which is vital to the Nation's health. Some people, however, also believe that another result has been economic disaster.

We do not agree, but certainly the very high cost to the car buyer of quickly conceived emissions control devices has had a negative effect on our vital automotive industry and at a very critical time in our economic history.

These emergency engineering programs at the automotive companies have cost on the order of $2 billion and the emissions control equipment on production cars has cost the buying public many additional billions of dollars. The lesson we can derive from this economic problem is that a great deal of leadtime is required to do basic engineering work and to translate this into low cost, mass produced automotive parts.

We believe we all came by this problem honestly. The public demanded clean air and the Congress properly responded with tough legislation. The technical background, both engineering and medical

unfortunately, was very weak at that point in time. All parties lacked information; the House and Senate Committees, the administrative agencies and the engineering community including the automotive industry. This, unfortunately, resulted in serious problems in the legislation and administration and even a lack of trust between industry and government.

Fortunately, we see a completely different picture as we approach the energy problem. In reviewing the questions that we have been asked by this and other committees, it is obvious that the committee members now have a good understanding of the technology and of the lead time required for engineering development. The officials from the various Government agencies that have appeared also show an excellent understanding of these factors. As compared with the early days of the pollution crisis, industry representatives, including top management, are better informed and have a better technical foundation from which to make recommendations.

I, therefore, conclude that a feeling of trust will develop, the problems will be faced enthusiastically, energetically, and realistically by all parties and there will be success in conserving our lower cost energy sources while protecting our environment and without damaging our economy.

Today, I do not wish to discuss the regulatory side of the Government's role, but, rather to limit my comments to the research and development side.

The Government should concentrate its expenditure on areas that can have a major influence on future low polluting, low fuel consumption engines. If you accept this, it immediately reveals what the Government should not be doing. It should not utilize its limited funds on the various types of piston engines. The automotive companies have large engineering organizations and vast development facilities dedicated to this area and they are already strongly motivated to meet the public demand for lower fuel consumption engines, smaller engines, smaller cars, et cetera. Because of the lack of technical information on emissions, there may have been in the past, some justification for Government expenditure on piston engines. However, with respect to fuel economy and in view of the capability of the industry, we see little chance of Government spending affecting the fuel economy of our future piston engines.

We, therefore, conclude that all of the development money should be concentrated on alternate powerplants that can, in the longer term future, have a very major impact on our environment and energy supply. The amount of these funds should also be substantially increased.

It should be a technology program rather than an effort to develop a specific engine that is ready for production. Complete engines could be developed but only for the purpose of demonstrating particular features of advanced technology. The automobile companies would then utilize those portions of the technology that are useful in meeting the market requirements.

With the new requirements of clean air and energy conservation and with the advance in technology, the piston engine no longer appears to be the best long term engineering solution. We must not, however, expect alternate systems to begin to affect our annual fuel consumption for at least 10 years.

A relatively small expenditure, by comparison to a typical NASA space program budget, for example, can have a very significant influence on future automotive propulsion systems.

A small portion of the Government finding of alternate powerplants should be spent on research activities which cannot have a definite schedule since technical breakthroughs are required. These would include such fields as advanced electric batteries and fuel, such as hydrogen manufactured from the energy produced by nuclear powerplants.

The major effort should be concentrated on the automotive gas turbine engine. The evidence that this is the automotive powerplant of the future is very strong. It has derived its technology from the billions of dollars that have been spent on aircraft jet engines, its development has been consistently funded by the major automotive companies for 20 years because of its long-term potential and almost every Government study of alternate powerplants in recent years has concluded that the gas turbine is the leading candidate.

My company has been developing automotive gas turbines for the past 18 years, in many cases under contract with the major car companies. We have been operating turbine powered cars on the streets of Detroit for 10 years and we are the only U.S. company, outside of the three major U.S. car companies, with an extensive background in this field. Our major business involves the development and manufacture of small aircraft turbojet engines, hence, like NASA, we a. in a position to transfer the aircraft engine technology to our automotive developments.

In spite of the turbine programs conducted by the automotive industry and the excellent programs conducted by the EPA's Advanced Automotive Power Systems Group, the total expenditure on this subject has been a minor part of that required to seriously expect the effort to result in an early replacement of the piston engine. Nevertheless, substantial progress has been made and the automotive gas turbine is already approaching the performance and fuel economy of the piston engine.

In 1971, an American Motors Hornet powered with one of our company's engines met the 1975 emissions standards without the need for any special equipment in the exhaust system, and a General Motors laboratory test this year with one of their engines indicated compliance with the 1977 standards. The potential of the automotive gas turbine for major fuel economy and performance improvements, as compared with the piston engine, is well recognized by the industry.

We believe that an accelerated program could result in prototypes in 5 years that would have 20 percent to 30 percent better fuel economy than the piston engine. This will require developments that permit the automotive turbine to run at the same high temperature level that we now use in the large fanjet engines powering our transport aircraft.

The Government should take the lead in accelerating this effort by expanding its funding of turbine component development programs and the demonstration of technology in complete engines, such as those being conducted by the EPA with NASA support. (I would not recommend the use of complete engines except that the technology developments are meaningless unless they are demonstrated in an

engine.) Such programs stimulate more activity and interest by the technical community in this field. It also provides the catalyst for generating more active programs within the car companies and provides the technical basis for justifying greatly expanded expenditures within these organizations.

Because of the importance of leadtime to the economic implementation of new developments in the car industry, we should not wait for the formation of the new energy agency but should increase the effort and spending rate in the various existing agencies.

In addition, the expenditures that are made should be concentrated on the automotive gas turbine to insure its success, rather than continuing to be disbursed broadly on activities that can have little impact on our future.

Specifically, we recommend that the Government issue contracts to industry in the amount of $30 million to $50 million per year for the next 5 years, with additional supporting work by Government laboratories. A portion of this expenditure should go to the automotive companies, when they are willing to publish results, such as in the Chrysler-EPA program. From the 5-year point on, we believe the car companies' own development and pilot production efforts would become very competitive and aggressive, and no further Government seed money would be required.

Taking this strong action now—that is, concentrating the effort on the most promising candidate and substantially increasing the effort—can provide the industry with the leadtime needed to make an economical transition to a new powerplant during the mid-1980's that will meet our desired energy goals.

In closing, we wish to emphasize that our great free enterprise system can best solve our economic problems with minimum interference by the Government and with regulations of a technical nature limited to those that are firmly established requirements. The purpose of the Government development expenditures that we recommend are not to interfere with our competitive system but to advance the technology needed to avoid future problems with our environment, energy resources, and economy, while allowing our lifestyle to continue to improve.

Mr. SYMINGTON. Thank you very much, Mr. Williams and Mr. Jolivette for this presentation.

There is one question which quickly occurs, and although it is not exactly an inconsistency, it does appear to involve ideas that seem to run counter to one another.

At one point in your testimony, you suggest that NASA shouldn't be trying to develop an engine, but should be exploring, conducting certain research objectives; and yet at page 8, you recommend that NASA concentrate on the automotive gas turbine apparently to the exclusion of other modes.

It seems to me if we are going to conduct essentially what is transitional research from basic to applied, we want to do it across the range of possible alternatives rather than concentrate on one, wouldn't you think?

Mr. WILLIAMS. I would like to make two comments.

I am not suggesting that the Government develop engines to the point that they are ready for production. I don't think anybody would

want to buy an engine developed by a Government committee. But it is necessary to develop complete engines in order to develop the technology of gas turbines. You need to do a lot of work on materials, on components of the gas turbine, compressors, heat exchangers, combusters, and then demonstrate those and modify them and develop the technology of engine design to utilize those items. And I pointed out that the auto companies then would take those portions of that technology that are practical from their market standpoint and incorporate them in their engine designs. But we should proceed with complete engines; otherwise, the program would be meaningless.

I am recommending that we concentrate on gas turbines. It is the only alternate powerplant and I don't classify the various kinds of piston engines as being truly alternates. It is the only basic type of powerplant that has been of interest to the car companies over the years. It is the only alternate powerplant that has had a lot of money spent on it already through the aircraft side, and I think from a practical standpoint, it is the only alternate that can really seriously eventually take over the automotive powerplant industry. All of the Government studies indicate it is the most promising.

Now, I am not saying we shouldn't work on very long-term programs such as batteries. You need about a tenfold improvement in batteries, so you need a technical breakthrough, and it is worth spending some money on this type of thing. What I am saying, if you would spend 90 or 95 percent of the effort on the gas turbine, that the Government could then, in fact, have some contributing good influence on our future automotive propulsion. I think spreading the money broadly is rather pointless. I don't think it really will influence the future.

Mr. SYMINGTON. Perhaps we need to define what we mean by the future.

Mr. WILLIAMS. Yes.

Mr. SYMINGTON. You would suggest that we devote 90 to 95 percent of Federal automotive research assistance funds to gas turbine problems. At what point would you expect payoff there in terms of a clean, efficient, and nonpolluting engine?

Mr. WILLIAMS. In 5 years we would have prototypes that have all the fundamental requirements; that is, efficiency 20 to 30 percent better than the improved piston engines.

In other words, far enough ahead of the piston engine that the car companies would be willing to really move into that subject aggressively.

Mr. SYMINGTON. In 5 years, at what level of funding now are you thinking?

Mr. WILLIAMS. I am saying from $30 million to $50 million a year for 5 years.

Mr. SYMINGTON. And how would this fund be administered? Would it go to auto companies directly or to research companies?

Mr. WILLIAMS. Well, I would suggest that on the order of 10 to 15 percent go to the car companies. It is important to have them involved and interested and they can help guide the effort into useful channels. I think they will have their own programs and will continue to have their own programs on gas turbines. But I think the majority of this money can be spent by the development companies, the aircraft engine companies that do have gas turbine experience, the research laboratory

can develop high temperature alloys and ceramic materials, all of the various contractors that have demonstrated capability to contribute to this kind of technology.

Mr. SYMINGTON. If it is $30 to $50 for the gas turbine research with 10 to 15 percent of that to the companies, if that $30 to $50 represents 90 percent of the total, you would contemplate the allocation of $5 million or so to the alternative modes across the board. I think my arithmetic is correct.

Mr. WILLIAMS. Well, I am saying that the long-term things, such as electric batteries, such as looking forward to the day when we want to manufacture fuel from electric power, such as hydrogen, I think those are very long-term things that require breakthroughs. I think it is worth some continual funding by the Government to keep up the pressure on that type of thing.

Mr. SYMINGTON. But, in your view, that could be a fairly low level of funding.

Mr. WILLIAMS. I am talking only of 5 percent of $50 million.

Mr. SYMINGTON. Yes.

Mr. WILLIAMS. If you really want to make an impact on the future automotive propulsion business which is not easy to do, if you want to make an impact, I think you have to take advantage of the work that has been done, the Government studies that have been done, the conclusions already reached that the gas turbine is the powerplant with the most potential and concentrate on that and try to have a real influence on what happens.

Mr. SYMINGTON. Do you see the gas turbine engine as being the operative propulsion unit, say, through the year 2000? Do you see it coming on line in 5 years or 7 or 8 years, and then being the engine for a decade or more?

Mr. WILLIAMS. I think you start to see production pilot runs and so on in 8 years and mass production coming along in 10 years, and I think that it will last for 20 or 30 years, we certainly have an abundance of fossil fuel that gets more and more expensive as we use up the supply and as we increase capital investment in order to utilize the diminishing sources.

Mr. SYMINGTON. Do you see it using other than oil derived fuel, coal, for example?

Mr. WILLIAMS. It does have the advantage that it works very well on a variety of liquid fuels. We can now run on diesel fuel. We can run on hydrogen without any difficulty. Coal derived liquid fuels would be fine.

Mr. SYMINGTON. Operating at optimum level, what percentage improvement over current gas mileage would you perceive for the average car if the engine were really in good shape?

Mr. WILLIAMS. The current design of automotive gas turbine engine is about equivalent to the present piston engine. It is better at full power and equivalent at 25 percent power, and is considerably poorer at idle. And when you operate on the Federal driving cycle, for example, you will come out about equivalent. This is on an up-to-date turbine design. After 5 years of further development we should have a 20 to 30 percent advantage over improved piston engines.

Mr. SYMINGTON. Now, that is a considerable saving, I am sure. I am just trying to think in my mind whether we can extrapolate the in-

creased use of vehicles that use the engine and the diminishing supplies of oil and the need to go, say, to coal or other forms of fuel.

Would you expect that to occur even given improved efficiency? Wouldn't you expect other than oil derived fuel to be used, say, in 20 years, even with the gas turbine engine if it were then incorporated into most cars, as I think you projected?

Mr. WILLIAMS. I think that is an interesting reason that I had not considered. I am not an expert on fuel reserves. I understand that the oil will last quite a while if we allow the price to go up. But certainly there is an abundance of coal derived fuels for the future, a tremendous abundance. That is an interesting point that the gas turbine would certainly run very well on that type of fuel. Whether that would come in 20 years or not, I really don't know.

Mr. SYMINGTON. Mr. Starkman of General Motors recommended, and I hope you get a chance to look at his testimony, against developing prototype engines. I don't know quite what the time frame was in his recommendation. He thinks Government should stick to fundamental research. I take it there might be some difference of opinion with him on your part that we are going to come up in 5 years with some ideas. We better have some prototypes, don't you think?

Mr. WILLIAMS. I don't know that there is a basic difference between Professor Starkman and me on this point. I think not because I also believe that the emphasis should be on the technology and that we shouldn't expect a car company to pick up one of these engines and run with it as a production engine. But I do believe that it is important under the government program to demonstrate that technology in a complete engine.

In other words, we have to develop these engines to operate at much higher temperatures. We are now operating at about 1,800° F. We have to go up to 2,200° F. which is the temperature now being used in big fan jet engines and this takes complete engine development to develop this.

Mr. SYMINGTON. Are there any safety hazards involved in going to these high temperatures?

Mr. WILLIAMS. No, there are not.

Mr. SYMINGTON. Mr. Brown.

Mr. BROWN. I had a sort of a general question. First, may I say, however, that I think your testimony is extremely helpful in its overall content and its evaluation of the situation with regard to the turbine engine.

You have indicated that a great deal of effort has been put on a turbine engine for automotive applications stemming out of the great success of such engines with aircraft.

Can you suggest why it is that we have not advanced to the stage of a production type turbine engine for automobiles in view of the amount of money that has been spent. Are there some differences with regard to their automotive environment as compared with the aircraft environment which causes problems that are of particular difficulty? Everyone agrees that the turbine engine has a lot of promise and a lot of money has been spent trying to develop that promise.

Mr. WILLIAMS. I think first of all, it will take at least 20 years to develop any alternate to the piston engine.

Mr. BROWN. We start with the fact that turbine engines are far more than 20 years old, depending on where you start as to when you get to the end of that 20 years.

Mr. WILLIAMS. It does take this long background of development to compete in an industry that has had so many units produced and has been refined from a production standpoint to the extent that the automotive engine has been refined. I think the big difference is production, the difference between our aircraft industry and automotive industry. There is a need for a great refinement in the design and in the manufacturing processes and development of low cost process.

Mr. BROWN. It just went through my mind that possibly one of the differences might be that the aircraft environment for the larger engines provides some factors which allow the operation at the higher temperatures that you suggested, that there is a greater—well, first, there may be different type of materials that could be used, there is a greater amount of heat dissipating ability in aircraft flying than there is in automobiles running on the highways.

Mr. WILLIAMS. There is more emphasis on output per pound of engine, and the turbine does extremely well in this arena. But the other factor is that the expenditure has been continuous for the automotive gas turbine because of its long-term potential. But it has remained a very small investment by the auto companies in comparison with their continued development of the piston engine, so we have been trying to catch up with a moving target, and I think we are finally getting there.

Mr. BROWN. Do all of the Big Three auto companies have turbine engine research programs?

Mr. WILLIAMS. Yes, they do.

Mr. BROWN. I appreciated your focus in your testimony on the role of the Government as a contributor to technology. I think most of the witnesses have tended to reflect this point of view, and some of those who reacted adversely to this legislation were fearful it would involve something more than technology—possibly the development of a—of actually putting the Government in the automobile production business which, of course, is not something that the Congress is likely to accept at the present time.

The specific proposal of this bill would have NASA engaged in the type of technological developments that might be necessary in this field, and you have indicated some of the areas, the development of materials that would be usable at high temperatures, and other items of this sort. You haven't spoken directly to this capability of NASA, but I presume that you would agree that they have a competence to make a contribution in this area.

Mr. WILLIAMS. Yes, they most certainly do. I think that you have a number of Government agencies with the technical and management capability for this kind of program.

I favor the new Federal agency energy approach, the emergency R. & D. approach, but I also favor making sure that people like NASA who have great capability and management capability be involved in this problem.

Mr. BROWN. While it is not directly before us, there is another bill bearing on this subject by Senator Tunney which also comes close to the thrust that you suggested, proposing that the Department of

Transportation be authorized to step up their research and development, primarily through the issuing of contracts to appropriate agencies for conducting the technological research that you have indicated, and your testimony bears on his legislation, as well, I think.

Mr. WILLIAMS. I have, of course, experience with the EPA, with their division under John Brogan. They certainly have excellent capability and I would like to see their program expanded and advanced. I think the Department of Transportation has excellent capability. The Army work in this area has been good. The National Science Foundation work has been well done. I think as I said, many of these agencies are in good shape to make contributions, and I don't like to recommend one agency as opposed to another. I simply recommend that you expand these efforts and particularly concentrate them——

Mr. BROWN. Just one last question, if I may. You have suggested on page 7 that a program of this sort would stimulate the automobile companies to step up their own activities in this field. This is something, of course, that is to be highly desired. I just want to ask you to reiterate your position here that you feel that it would collapse the timetable for the process of getting a workable alternate engine if there was the stimulation as provided in legislation of this sort.

Mr. WILLIAMS. I think we should emphasize this would be seed money, and that it shouldn't go on and on, that it should have a definite time phase and should definitely plan on the automobile companies picking up the main effort, gradually picking it up during the next 5 years, and by the end of 5 years I believe they would be off and running.

Mr. BROWN. Thank you very much, Mr. Williams.

Mr. SYMINGTON. In that connection, you mentioned of the $30 to $50 million of Federal seed money that about 10 or 15 percent of that money would go to the auto manufacturers. That would be like $3 to $5 million to the companies and yet you see the companies as being the primary focus of research investment. I take it that all the remainder goes to support other research and ventures outside of the automobile companies, but which, I take it, are somehow cranked into Detroit's research at some later date down the stream.

Mr. WILLIAMS. They are already. They are companies that are already involved in the automobile industry as suppliers. They are jet engine companies that are already participating in the EPA turbine programs. We have a lot of technology that is of interest to the future of the auto turbine.

Mr. SYMINGTON. What level of funding do you expect from the companies to meet their obligation in this respect, if they were to get $3 to $5 million from the Government, divided between 3 or 4 companies, that would be a million apiece. That isn't too much. What do you expect from them per annum in this area?

Mr. WILLIAMS. Well, of course, by the fifth year, I would expect very substantial programs to be in effect. They spent, I believe, on the order of $2 billion on emissions development since our country became very interested in the subject. And I think that a good part of that same kind of an investment would be made in their future powerplant activities in time, and as they move to production.

Now, I would expect each of them to be spending, say, in 3 to 5 years $50 million each on automotive turbines and steadily increase from that point on.

Mr. SYMINGTON. Drawing on my recollection of what the company spokesmen said, one thing I recall was that they don't expect to carry the full burden of research in this field; they are spending so much time and effort meeting immediately problems such as emission controls, this kind of thing, they might like to see that formula slightly changed, the one that you recommend.

On the other hand, EPA testified that it was Detroit's entirely to develop. I'm trying to remember the figures. Let's take a peek here.

Well, in 1973 GM invested in alternative power research, research direct expenditures, $23,424,000; Chrysler, $3 million? Should we say, then, that the automobile companies should invest 24 or 25 times as much in this area as they get directly from the Federal Government seed money program?

It would appear if they got a million dollars from us, in 1973, that is what would be the case.

Mr. BROWN. Would the gentlemen yield there?

I would suggest that a good part of that is going into research on the present type of propulsion systems, the piston engine, or other type of internal combustion engine, and a very modest part of that is going into the type of thing represented by the turbine or other unconventional engines.

Mr. WILLIAMS. Of course, the real investment that they have to make starts when they decide that they are serious and they are really going to go ahead with a particular type of engine. At that point, they have to do a lot of engine development work, turbine work, road testing of large numbers of engines, development of manufacturing methods, and so on.

What I am saying is that after we get through this seed money phase, their costs are going to go up very rapidly when they decide they really want to go ahead with this.

In the interim, I think they will be gradually increasing their present level of effort on gas turbines and they will be stimulated to do this by the activity generated by this seed money.

Mr. SYMINGTON. Any further questions?

Mr. BROWN. No.

Mr. SYMINGTON. Thank you very much.

Mr. WILLIAMS. Thank you very much.

Mr. SYMINGTON. We appreciate your testimony.

Our next witness is Mr. Jay Carter, Jr., of Jay Carter Enterprises of Burkburnett, Tex. Mr. Carter and his father have been engaged in development of a steam engine for automotive use which was described quite favorably by an earlier witness. Mr. Carter is here to give us further details on his company's work. We welcome you to the committee.

Mr. CARTER. Thank you. It is a pleasure to be here today, and we consider it an honor to be able to testify on what we have done and give our comments on your bill. As you said, I have my father here with me. He is president of Texas Reinforced Plastics, and helps me out a lot, although he has a pretty big job with his own company.

Mr. SYMINGTON. We are glad to have Mr. Carter, Sr., with us.

Mr. CARTER, JR. I have a prepared statement here concerning our comments on the bill. I also have a prepared statement on our Carter Steam Car which I'll be glad to read and I have a short movie showing our car. It is about 5 minutes long.

Mr. SYMINGTON. You can present your testimony any way you like.

Mr. CARTER, JR. In the interest of saving time, I will read the comments to your bill and if you have any questions at that time, we will stop and answer them or go into the statement on the Carter steam car.

[A biographical sketch of Mr. Carter, Jr., and Mr. Carter, Sr., follows:]

JAY W. CARTER, JR.

Education

BSME, Texas Technological College, 1968.

Experience

Bell Helicopter Company, 1968–1970. Joined Bell as a Research and Development Engineer. Worked as designer on Model 300 proprotor blade and on the D 212 thin tip extended chord blade. Principal designer of D 270 proprotor blade and folding mechanism. Design engineer on D 272 folding proprotor blade.

Jay Carter Enterprises, 1970 to present. Worked on design and development of Rankin Cycle system which was installed in a Volkswagen squareback.

Professional societies

American Helicopter Society, American Society of Mechanical Engineers, Texas Society of Professional Engineers.

Sampling of papers and publications

(1) A Student's Designed and Built Gyrocopter, presented to ASME Southwest Regional Conference, Spring 1967.

(2) How to Design Your Own Airplane, presented to the Experimental Aircraft Association, Dallas Chapter, March through November, 1969.

Miscellaneous

Manager of Texas Tech Science and Engineering Show 1965–1966, Vice-President Texas Tech Student Association 1967–1968. Co-inventor on patent application for advance technology proprotor blade at Bell Helicopter. Designed and built two gyrocopters while going to school. Started building an all fiberglass pusher airplane while at Bell Helicopter. Vice-President Experimental Aircraft Association, Dallas Chapter and Wichita Falls Chapter. Private pilot's license, single engine land.

J. WAYNE CARTER, SR.

Born June 26, 1923. Married, four children.

Education

High School, Ponca City, Okla., 1942.

Aircraft Engine School, Duncan Field, Tex.

Army Specialized Training Program, Engineering—Western Maryland College, Westminster, Md., 1943–1944.

BSME, Texas Tech University, 1946–1949.

Experience

Roustabout in oil fields, summers 1939, 1940, 1941.

Part time machine shop work, 1946, 1947, 1948.

Texas Power & Light Co., Trinidad, Tex., Plant, February 1949–October 1952, assistant mechanical engineer.

Industrial Generating Co., Rockdale, Tex., October 1952–September 1955. Chief mechanical engineer in charge of all mechanical maintenance at the 360,000 Lignite burning power plant.

Fish Engineering Co., Houston, Tex., October 1955–February 1957. Design and development engineer on calcium chloride dehydration units being developed for gas wells.

Black, Sivalls & Bryson, Inc., Oklahoma City, Okla., March 1957 to August 1960. Project engineer at the research lab. Designed special machines for winding large diameter fiberglass tanks. These machines were used to wind the first successful Polaris and Minuteman missiles made with glass fibers.

Black, Sivalls & Bryson, Inc., filament structures division, Ardmore, Okla., March 1957–October 1963. Chief engineer. This division was formed and a large manufacturing plant built as a result of the success at the research lab in Oklahoma City. All sizes of filament wound fiberglass tanks were made at this facility as well as several hundred Minuteman and Polaris missile chambers.

Wichita Falls Research Co., Wichita Falls, Tex., October 1963–April 1964. Resigned from BS & B to form Wichita Falls Research Co. Started design and development work on a machine to continuously produce filament wound fiberglass pipe.

Texas Reinforced Plastics, Inc., Burkburnett, Tex., May 1964 to present. President and major stockholder. Sold pipe manufacturing equipment and patent application to CIBA Products Co. in February 1965. T.R.P. has continued to develop new products, and design and build special machinery for the CIBA pipe operation.

Jay Carter Enterprises, Inc. Formed in 1969 to develop new ideas and to do contract work for Jay Carter Associates. President.

Patents

Approximately 10 patents have been issued in my name, with several in foreign countries. Several more patent applications have been filed in the patent office.

Miscellaneous

Member, American Society of Mechanical Engineers code committee for plastic pressure vessels.

Member, Experimental Aircraft Association.

Member, Popular Rotorcraft Association.

Member, Steam Automobile Club of America.

STATEMENT OF JAY CARTER, JR., JAY CARTER ENTERPRISES, BURKBURNETT, TEX., ACCOMPANIED BY J. W. CARTER, SR., PRESIDENT, TEXAS REINFORCED PLASTICS, INC.

Mr. Carter, Jr. We, at Jay Carter Enterprises, are honored to be invited to appear here today, and appreciate the opportunity to discuss our views on H.R. 10392. Accompanying me today is my father, J. W. Carter, Sr., who is president of Texas Reinforced Plastics, Inc., a research and development company. Six years ago he started Jay Carter Enterprises with the goal of developing a steam powered automobile that would be competitive with the internal combustion engine.

We support bill H.R. 10392 and approve of the use of NASA for ground propulsion systems research and development, because we feel there is a need for the development of an efficient, clean-burning propulsion system with multifuel capabilities. However, NASA's program should remain separate and independent of any other agencies formed or that may be formed for this type work. We believe that competition and the incentives it develops are just as important in government as it is in industry.

There are two main items which must be incorporated into the project to insure that the best solutions are obtained in the quickest and most efficient manner.

First, it is necessary that competition and the incentives it develops are generated between two or more government agencies striving toward a common cause. There may be overlapping efforts between the

agencies, but because of the competition and the desire between the agencies to get credit for having the first and best solution, the overall time and costs will be less. Certainly we want, as quickly as possible, to have an energy efficient, low polluting, multifuel power system, but at the same time we don't want to rush into something that we are going to have to live with for the next half century. Competition between government agencies will help assure that this won't happen.

Additional incentives must be given to those corporations awarded the contract. A cost-plus contract is not conducive to efficient, creative performance. If the Government expects to get qualified companies to bid on their contracts or to get really aggressive, creative work out of their contractors, then the contractors should be permitted to retain at least half of any profits, royalties, or patents which are obtained as a result of their efforts.

I understand that NASA's primary effort will be in the area of management, analysis, tests, and evaluation and that the bulk of the work is accomplished outside the Government, in the private sector, where it belongs. Therefore, they will be inviting requests for proposals from industry. I strongly suggest that they do not limit proposals to large companies. There is also creative ability in small firms.

As I mentioned earlier, we have been working on a steam system for an automobile. We recently had our steam-powered Volkswagen tested by the EPA lab in Ann Arbor, where our car became first of any type to meet the original 1976 emission levels without any add-on control devices.

We will be glad to answer any questions about our steam car, the EPA test results, or any comment we have made about H.R. 10392. If there are no questions we can go on to describe our system, and what we have done.

Mr. Symington. I think we can go ahead unless Mr. Brown has a question here.

Mr. Brown. I think we ought to go ahead.

Mr. Carter, Jr. We recently completed tests on our steam-powered Volkswagen at the Environmental Protection Agency lab in Ann Arbor, Mich., where our car became the first of any type to meet the very strict original 1976 emission levels without any add-on emission control devices.

Besides getting extremely low emission, our fuel economy was 24.7 mpg at 30 mph, 20.9 mpg at 50 mph, 14.9 mpg over a cold start 1975 driving cycle, and 17.3 mpg over the Federal highway driving cycle.

While these fuel economy numbers are fair, they do indicate the potential for very good fuel economy, equal to or better than 1974 automobile fuel economies, based on the tested baseline data and the known relative easy areas for improvements. Based on the results of our first steam car, our second car will have emissions at least one-third of the original 1976 emission levels, over 25 mpg at 55 mph, over 20 mpg over the Federal driving cycle, and a drive-away time from a cold start of 15 seconds or less.

Initially, research was renewed on the steam engine because of its inherent low emissions, but besides having very low emission and excellent fuel economy, there are several other factors which make the steam engine an excellent alternative to the internal combustion engine.

The steam system can use a variety of different fuels. It is not limited to burning only petroleum products, as a matter of fact, it can burn coal tar, a derivative of coal. There is reported to be enough coal in the United States to supply our energy needs for 800 years. So the sooner we change to burning coal products in our cars, and saving our petroleum products for other needs, the better off we are.

Also, the steam engine has the potential for extremely long life, on the order of at least 500,000 miles before overhauls. The application for taxis, buses, and trucks is ideally suited.

We have taken a fresh and new approach to many of the problems associated with a steam-powered vehicle, which is obvious since our first complete system fits into the Volkswagen engine compartment with the exception of a small ram-air condenser located up front. The total system weighs only 120 pounds more than the original internal combustion engine, and includes the condenser weight which is made out of lead and brass. Little effort was made to conserve weight on the first prototype.

Our automobile powerplant is a completely closed system which means we do not have to add water. We use the same water over and over again. We also do not lose any oil, which means we can virtually bathe our piston rings in oil. It is because of the almost perfect lubrication in our system, that enables our engine to last so long.

The expander puts out over 90 shaft horsepower from 35 cubic inches at 2,000 psi steam pressure and 5,000 rpm. The steam temperature is constant at 1,000° F.

The car was first driven around Burkburnett on March 15, 1972, over 2 years ago and now has accumulated over 4,500 road miles.

Drive-away time from a cold start as tested by EPA over the 1975 Federal driving cycle was 28 seconds and 32 seconds.

My father and I are both mechanical engineering graduates of Texas Tech University. My father is president of Texas Reinforced Plastics, Inc., a research and development company that develops reinforced fiber glass pipe and products for the oil and chemical industries. He developed the first successful glass filament wound rocket motor chambers for the Polaris missiles.

As a result of our recent tests, the steam engine can no longer be ignored as a possible practical alternative to the polluting internal combustion engine. The steam engine may be given a second chance to supply the power needs of the world as it did in the early years of our industrial revolution.

[The following attachments of Mr. Jay Carter, Jr. are as follows:]

	Miles per hour	Gear	Miles per gallon	HC, 0.41	CO, 3.5	NO_x, 0.4	T_1[1]	T_2[2]	T_A[3]	T_3[4]	T_6[5]	P_E[6]
1st set of steady State data	10	1	10.5	0.48	3.37	0.53						
	10	2	13.7	.57	2.49	.30						
	20	2	17.1	.2	1.42	.29						
	20	3	20.9	.27	1.61	.22						
	30	3	21.8	.08	.68	.25						
	30	4	23.4	.11	.9	.22						
	40	4	22.8	.03	.44	.25						
	50	4	20.0	.01	.09	.28						
	60	4	17.4	.01	.07	.34						
1st highway driving cycle			16.3	.04	.47	.32						
1st Federal driving cycle			12.7	.34	1.33	.39						
2d set of steady State data	10	1	11.8	.31	2.56	.4						
	10	2	14.2	.48	2.59	.51						
	20	2	18.4	.05	.90	.29						
	20	3	21.8	.28	1.18	.24						
	30	3	23.8	.05	.41	.27						
	30	4	24.7	.09	.65	.22	550	740	645	830	150	550
	40	4	23.7	.02	.24	.25	760	930	845	975	150	675
	50	4	20.9	.01	.16	.28	820	950	885	980	150	775
	60	4	17.4	0	.11	.34	870	950	910	980	140	925
2d highway driving cycle			17.3	.02	.28	.31						
2d Federal driving cycle			14.9	.399	1.08	.33	(7)	(7)	(7)	(7)	(7)	(7)

[1] T_1 equals temperature of steam line connecting bottom 2 cylinders.
[2] T_2 equals temperature of steam line connecting top 2 cylinders.
[3] T_A equals average temperature feeding to cylinders.
[4] T_3 equals boiler exit steam temperature.
[5] T_6 equals temperature of water entering boiler.
[6] P_E equals pressure of steam at expander.
[7] Large HC number due to poor ignition at wide open fuel flow.

NOTES

The 2d set of data was run exactly the same as the 1st set of data, yet in every case the fuel economy was better in the 2d set of data. This increase in fuel economy is believed to be as a result that the rings were seating in. At the beginning of the tests there were less than 400 mi on the new rings. The fuel economy may still increase more as more time is put on the rings. You might also note the low TA due to poor insulation and radial configuration and the efficiency to be gained here and by increasing T_6.

As a matter of convenience, many of our accessories are driven by 24 v electric motors, running on 12 v. The electric motors are only about 50 percent efficient and the alternator also is only about 50 percent efficient, therefore, by driving most of our accessories mechanically instead of electrically, we can reduce the excessory load which the engine sees by as much as 50 percent.

We do not need a condenser fan for steady State speeds up to 70 mi per hour yet, for convenience sake, our fan is driven all of the time. At 50 mi per hour the 14 inch diameter fan turns at 4,250 rpm, and is absorbing a significant amount of horsepower.

Mr. SYMINGTON. Thank you very much, Mr. Carter, for an interesting and informative statement.

Did you have a film of this car that you wanted to show us?

Mr. CARTER, JR. Yes, we do.

Mr. SYMINGTON. Why don't we look at that now.

[At this point a short film was shown.]

Mr. CARTER, JR. This film was taken almost 2 years ago in October 1972. It was just before publicly releasing the fact that we had been building a steam engine for an automobile.

We felt like it was better to get a system built, developed, and put in a car before telling people what we had.

There have been a lot of people who talked about what they were going to do. There have been a lot of false starts with a steam car and we just didn't want to be classified in that category.

So very few had heard about our system until October 1972, when we invited Mr. Tifman who was then Director of the California State Legislature Federal Office, to come out and see us.

These shots were taken on the day that he came out.

You can see we have added some extra louvers on the fender well for more air flow. We have a large condenser in the rear. We added a small ram-air condenser up front. We have no trouble condensing all of our steam on a 100-degree day at 70 mph. As a matter of fact around June of last year, we drove our car back from San Antonio in 100-degree weather without any appreciable loss of water.

These shots were taken on our drive to the airport to pick up Mr. Tipman.

At this time, our system was completely automatic and by that I mean, you turn the key on, 20 to 25 seconds later, The car is ready to drive off. It operates exactly the same as a regular Volkswagen. You shift gears. We use the standard Volkswagen four-speed transmission. We have taken a new approach on our engine system which has enabled us to do a lot of wonderful things which no one else has been able to do. We have a valve system which requires no lubrication. It operates at high temperatures and high pressures since it has no high pressure nor high temperature seals. We operate at 2,000 psi pressure and 5,000 rpm which is the reason we can develop 3½ horsepower per cubic inch. We operate at a constant expansion ratio at 11.3 to 1, which enables us to get the most amount of energy out of the steam before we exhaust it into our condensers.

Here are some shots from the air. My father was doing the flying. I am doing, I would say, around 75 miles per hour. I wanted some nice shots passing several trucks. The speed limit at that time was 70 miles an hour. I have another shot where we are driving about 80. I think this is where we are going 80. The trucks along the flat highways of Texas drive a good 70 miles an hour. But even at 80 miles an hour, we are not at full throttle.

This is our shop. It is an airplane hangar. When we built this car there were two people on the payroll, a machinist and myself. My father helped a lot as a consultant. We have since hired two other fellows, a draftman and another machinist.

This is the instrument panel, although most of the instruments are in the glove compartment. We do a lot of driving of our car on the highway and, of course, it is set up so we can run tests on it.

Here is a view of the engine compartment. The white that you see is the insulation on two of the four cylinders.

Here is a shot of the expander. It is a 4-cylinder radial, 35 cubic inches displacement. The water pump is an integral part of the engine. The total package of what you see there weighs only 114 pounds and includes the expander, feed water pump, oil pump, throttle valve, and insulation. Our million-Btu, capacity boiler weighs 125 pounds, and that includes the blower motor and all the automatic controls. As I said, our total system weighs only 120 pounds more than the I.C. engine. This being the first prototype, I was very conservative in all my stress analysis of the engine, and of course, we had to build everything. We had to build the crank shaft, pistons, connecting rods, and cylinders. We had to develop all of our automatic controls, our temperature sensing units, our oil-water separator, and we even did the work on our condensers.

The fact is, we have taken a new approach on nearly every item on the steam system.

Mr. SYMINGTON. Thank you for a very interesting film.

I am going to have to leave at this time. Mr. Brown, will you take over the chair? I certainly would like to see that car one of these days.

Mr. CARTER, JR. We considered bringing it up here, but its a long way to bring the car. We had it at EPA and took a lot of people for a ride there. If you are ever down in our area, we would be glad to take you for a ride in our car.

Mr. SYMINGTON. We appreciate your testimony very much.

Mr. CARTER, JR. Thank you.

Mr. BROWN. I certainly want to express the appreciation of all of the members of the committee, and our interest in the work that you have done, Mr. Carter. The first question that occurs to me, and I imagine will occur to a lot of people, is how is a small operation like your own able to be as successful as you have been in developing this prototype car when the major automobile companies seem to have despaired of success.

I am sure there are legitimate reasons why Ford, for example, has decided not to continue with a major emphasis on the steamcar, and other major companies are the same way. But I'd like to hear your reaction to that. Do you think small companies are intrinsically better than big companies?

Mr. CARTER, JR. No; I don't think that is necessarily true. I think a lot of our success is probably due to attitude. We are privately financed and have not had the money to afford to make many mistakes, so we have to be very careful with what we do, and of course, because we stand to gain everything that we develop, the incentive is there for us to work on it nearly every minute of our working day. I take the project home with me. I take it to bed with me.

It is very easy to spend a lot of money when you get started on the wrong approach. That happens sometimes in research and development. It is very unfortunate when they spend a lot of money on the wrong approach, and it is unfortunate that they have given up so soon.

We have been fortunate, I believe, in that we have taken a good approach, and it is one that enabled us to do these nice and wonderful things.

Mr. BROWN. I want you to do justice to the big car companies. They say there is an intrinsic limit to what can be done with the steamcar in terms of fuel economy and so forth, theoretical limits which do not in their opinion justify devoting a major emphasis to it.

Are they being shortsighted in this analysis?

Mr. CARTER, SR. You see, there are theoretical limits, if we believe all the theory. But the thing is that the people do not know. No one knows how close we can approach those theoretical limits. In other words, when we design a system, is it going to be 40 percent of that theoretical limit or 85 percent of that theoretical limit? There, I think, is where the problem is. We only know from past experience how close we can come to that theoretical upper limit. If we base our thoughts on technology developed back in the 1920's and 1930's, and don't use modern technology, and don't move with the times, and we build a steam engine like 40 years ago, then there is no way we can complete with the I.C. engine. We have taken a fresh, new approach to this thing. We have thrown away the book and started over from scratch, so to speak. We operate at high pressures and high temperatures, and

we have a system that we can go to 3,000 pounds of pressure if we need to.

Mr. BROWN. We have been told by others who are working in this field there are certain problems with materials that occur at the higher pressures and temperatures?

Mr. CARTER, JR. You see, we operate at relatively low temperatures, 1,000° requiring no special materials, while the Sterling engine is going to be operating at nearly 1,500°, and the gas turbine, to get its efficiency, is going to operate at 2,000°. We have potential for going up to 1,200° in our present design with no material changes, but we should be able to equal the efficiency of the I.C. engine without using temperatures of more than 1,000°.

Mr. BROWN. Just one additional question. With the thrust of this bill which would authorize NASA to provide assistance in solving some of these technology problems, do you see this as a role which would contribute to the faster development of an alternative engine?

Mr. CARTER, JR. Yes, sir, I sure do. If you consider what we have done in 4 years on a very shoestring basis, then it stands to reason that as more money is put into our approach, then very significant gains can be realized and certainly some money by the Government would be very helpful. We have not had very much encouragement from anybody, and certainly we would like to see some help. I think the motor companies have kinds of tunnel vision when it comes to the steam engine. They decided its no good based on technology of 20 or 30 years ago, and that there is no future in it, and it is very sad. It is very sad indeed.

Mr. BROWN. Do your plans call for going into competition with the Big Three in the future?

Mr. CARTER, JR. What we would like to do, of course, is to sell our patent and development work to some major motor company. That is, the place where automobiles will be produced for the next 50 years. We are presently working on a second system in the event we can't interest the motor companies with the first one. We feel it will be unquestionably superior to the I.C. engine and it will blow the lid off of this thing.

Mr. BROWN. Mr. Winn, did you have any questions?

Mr. WINN. Thank you.

I was wondering about the money involved, to set aside $30 million for 5 years, do you think that is enough to fund a research program like you have in mind or for the entire research to be done, is it too much to do?

Mr. CARTER, JR. Well, our efforts don't require a lot of money. Some other organizations, because they are larger and probably they are not as efficient, do require more money. It is hard for me to say exactly; $30 million does seem like a small amount considering the impact and the importance of what we are working on. The sooner we do something about it, the better off we are all going to be.

Mr. WINN. I don't know how many companies such as yours are working on this. We see feature stories, some are publicizing their findings, some are still working behind the scenes and keeping their patents and ideas very secret. The question comes up, I think, do we need still another agency in this field when we have got fractionation already

in the effort by the Department of the Army, and EPA, and the Department of Transportation and still others?

Mr. CARTER, JR. Well, granted there are several agencies that are doing work but their scope is very narrow. They have taken one approach and I think some of them are very wrong. I don't feel like they are going to make it with their approach. The more agencies that you can have, the better chance you will have of not running down a blind alley.

I like competition. I think it generates a lot of incentives, if it were managed right, and I think competition between Government agencies would be just as helpful and provide the same incentives as competition in industry.

Mr. WINN. I don't think there is any doubt that competition is good, and most of us on this committee feel competition is healthy. At the same time, the energy crisis was simply a good example of where we had so many agencies and committees, 17 out of our 28 committees were involved in some parts of trying to solve the energy crisis. It seems to me like we are going off in all directions. I wonder if we might be doing the same thing?

Mr. CARTER, JR. I agree that theoretically it does sound good to have all these agencies brought together under one heading, and maybe it will work. But when you have only one central group, the group is only going to be as good as the people that are put in charge. And if these people are more interested in their own political gains, their own agencies or building up their own bureaucracy, or what not, it stands to be a disaster that we cannot afford. There needs to be some checks and balances and I think competition is a good check and balance for this type of, you know, situation that could occur.

Mr. WINN. You may have covered this, do you have any other cars or do you just have the one prototype?

Mr. CARTER, JR. Well, unfortunately, we could just afford one prototype. For our next generation of cars, we are going to build at least two systems and have another system that will be on the test stand all the time. In the past whenever we had a problem and wanted to do some work, our whole system was shut down. And it hurt us, but, of course, we had no other choice. We asked for help, but, we are not a very large company and a lot of people say, "what makes you think you can do it when large companies can't do it."

Mr. WINN. What is your answer?

Mr. CARTER, JR. What is my answer?

Mr. WINN. If people ask you that, what is your answer?

Mr. CARTER, JR. It is really hard to dispute. About all we can say is; we have taken a different approach, just look at what we got. Unfortunately, it took us almost a year of concentrated effort before we could get EPA to test our car. It is doubtful as to whether they would have ever tested our car if it hadn't been for the help of some of our Congressmen. That has been the situation.

Mr. WINN. It may be they have their heads in the sand and won't take it out.

Mr. CARTER, JR. They have their own program and, I understand, they probably have a lot of people coming to them who say they have a solution and so after a while they don't pay attention to anyone.

Mr. WINN. What you gentlemen have said is pretty discouraging to those of us who are trying to accomplish something in this field, and if we are closing our eyes or ignoring the possibilities, many people have said that it may well be a small mechanic somewhere working out of a small garage or in the back of a plant or something that would come up with the final answer to this.

Mr. CARTER, JR. There are a lot of small companies across the country that are working on similar projects. I think they probably have had the same negative response that we have had.

Mr. CARTER, SR. As you probably know, there are a lot of very smart people in these big companies. In fact, there are smart people all over the world. Even though you have a big company, there are probably only one or two men in that big company that are calling the shots. This is where the trouble comes in. A lot of their engineers know the boss is making a mistake. They are not in a position to call the shots. Just because it is a big company doesn't mean they are going to be the one with the answer. I have been in competition with big companies all my life and big companies don't scare me as far as competition. Their money scares me.

Mr. CARTER, JR. They do have the technical potential, but it is difficult for them to utilize it to the fullest extent.

Mr. WINN. Thank you very much.

Mr. HAMMILL. I'd like to ask a question of Mr. Carter.

The previous witness, Mr. Williams, said that he felt that the major effort should be concentrated on the automotive gas turbine engine. He said the evidence that this is the automotive powerplant of the future is very strong. I gather that you wouldn't agree entirely with that.

Mr. CARTER, JR. No, I wouldn't.

Mr. HAMMILL. One of the assertions that he made was that almost every government study of alternative powerplants in recent years has concluded that the gas turbine is the leading candidate to replace the piston engine, is that true in your opinion?

Mr. CARTER, JR. That may be since many government studies have been based on steam technology developed in the 1920's and 1930's. I would also like to point out that there have been government appropriations both in California and by the Federal Government to build a steam engine, but so many times they put such timetable restrictions on the project that in order to meet that time schedule, companies do no have the time to devote, to developing a new system. They have to go with something that is pretty much already established. We try to get something done as fast as we can, but in the interest of coming up with something new or working out a better solution, we don't have a time schedule as such. We can take the time and get the job done right and then move on.

Mr. CARTER, SR. I have been in the steam business for 30 some years, and I have built several steam engines, and I recognized, 10 or 15 years ago that what we needed was a new approach to this steam engine. And one thing that was needed was a steam admission valve that would let an engine run at higher rpm's. High rpm's is something modern. Higher rpm's is something that didn't exist in a steam engine 30 and 40 years ago. If you are going to compete with a lightweight internal-combustion engine, you are going to need high rpm's. That

is the first requirement. Also if you are going to be modern, you need to operate at high pressure. That means you will have to have a design that will operate at high pressure. At the very beginning, we realized this. The first 2 years, we were doing exploratory work. We were trying to find that solution, and we knew we had to have it before we could spend much money. That is what we were doing the first 2 years, developing the steam admission valve. After that we were ready to start spending money on building a steam car.

Mr. HAMMILL. Earlier witnesses, though, have mentioned the theoretical limits of steam. I would like to explore that further with you. Mr. Brown already brought it up. Your response, as I recall it, was along the lines that while there are theoretical limits, by the use of advanced technology, and so forth, you can achieve more within these limits.

Mr. CARTER, SR. Yes, sir.

Mr. HAMMILL. If there are, in fact, theoretical limits, however, then the best possible steam engine can only achieve a certain level of performance. Now, how would that level of performance compare with other alternatives such as the gas turbine?

Mr. CARTER, JR. I would like to answer that. Those theoretical limits were probably based on 1,000 degrees. That was the upper limit that previous technology would allow a reciprocating steam engine to run. We are now capable of operating our engines from 1,200 degrees to 1,300 degrees. Strictly from a layman's standpoint, if the steam wasn't more than just theoretically efficient, it wouldn't be used to power our large powerplants for producing electricity. The theoretical efficiency can be very high if you go to the higher temperatures and pressures. Our design enables us to go to these higher temperatures and pressures. One other point, the internal combustion engine is most efficient at full throttle. If you compare the best efficiency of the steam engine with the best efficiency of the internal-combustion engine, they are pretty close to one another but the internal-combustion engine under most driving situations operates at part throttle, maybe one-fourth of full throttle. Here the internal-combustion engine efficiency starts dropping off drastically, so that normally its operating condition is not at its peak efficiency, but something significantly less that that. The steam engine, on the other hand, can be designed where it operates under cruise conditions at its peak efficiency.

Peak efficiency of both systems would be very close to one another, but the fact that the steam system can operate in an automobile at peak efficiency, while the internal-combustion engine operates at less than its peak efficiency, gives us a very significant advantage just on that point. We can also operate at higher temperatures than what we are presently using. We are going to beat the internal-combustion engine. There is no question about it, just based on our test results and I know the engineers at EPA are also aware of our test results and the very easy areas for improvements. Our next car will unquestionably prove that point.

Mr. HAMMILL. In that regard, have you discussed with the research elements within the automotive industry, the Big Three, let's say, what you have done? Have you discussed your patent situation with them?

Mr. CARTER, JR. We have sent them a letter since our test results. We felt like it was meaningless to do anything before we had some good third party test results. We got a confirmation from Ford Motor

Co. that they had received our letter, and that they were looking into the matter. That is all we have received so far, and I am afraid that is all we will see. What I think may happen based on past history, is that some aggressive, progressive foreign car manufacturer will take what we got and start producing and bringing steam cars into the States and force Detroit by sheer economics to get serious. This is what happened to the Wankel engine and I would hate to think that is what may happen to steam, but it could.

Mr. CARTER, Sr. I am not afraid. I hope that is what happens.

Mr. CARTER, Jr. I would like to see the American companies do it first. I would just because I like the United States and what it stands for, but maybe that is the kind of pressure Detroit needs.

Mr. HAMMILL. By the way, the people in the automotive industry in Detroit aren't convinced that the Wankel engine is here to stay.

Mr. CARTER, Jr. No; they are not. They spent $50 million for the right to produce it and then another $150 million for patent investigation and other research. I maintain they could have gambled just a tiny fraction of that on what we have done and come out much better.

Mr. CARTER, Sr. That proves the automobile companies are not too smart or better. There were people 10 years ago that told them that this engine is not efficient.

Mr. HAMMILL. They still feel it is not efficient?

Mr. CARTER, Jr. Yes, but they spent a little money to find out.

Mr. BROWN. Are there any further questions?

Mr. WINN. I have no further questions.

Mr. BROWN. Thank you very much, gentlemen. I assure you that you have provided the committee with a most interesting example of what American ingenuity can accomplish and we are very pleased to have you here this morning.

Our next witness is Mr. Robert U. Ayres, Vice-President of International Research and Technology Corp. We are very pleased to have you here this morning, Mr. Ayres, and we look forward to your testimony.

Mr. AYRES. Thank you very much. With your permission, I will read the statement and add some interpolations at points based on ideas that occurred to me since I read some of the other testimony and also I may, with your further permission, add a few comments at the end.

Mr. BROWN. You have heard the testimony of the two earlier witnesses and anything you care to say based upon that will be welcome, also, of course.

[A biographical sketch of Dr. Ayres follows:]

ROBERT U. AYRES

Ph.D., University of London, Vice President, International Research and Technology Corporation. Dr. Ayres is a pioneer in the rapidly growing field of technological forecasting and technology assessment, and an authority on environmental pollution and transportation technology. In 1962, Dr. Ayres joined the research staff of the Hudson Institute where he remained for five years before moving to Washington, D.C. in 1967 to become a visiting scholar at Resources For the Future, Inc. He is the author or co-author of several books: *Technological Forecasting and Long Range Planning*, *Aspects of Environmental Economics: A Materials Balance-General Equilibrium Approach*, with Allen V. Kneese and Ralph C. d'Arge, and *Alternatives to the Internal Combustion Engine*, with Richard McKenna. He has also published numerous articles and

papers on topics in theoretical physics and economics as well as technological forecasting, urban transportation, environmental pollution, energy and other subjects. Dr. Ayres has been a consultant to the National Academy of Sciences Committee on Emergency Planning, the Office of Management and Budget, the OECD, and is currently a consultant to the United Nations Statistical Office on environmental statistics. He has served as a member of the National Academy of Sciences Committee on Technology and Water, the National Materials Advisory Board Committee on Technical Aspects of Critical and Strategic Materials, and the Highway Research Board Subcommittee on New Transportation and Technology. He is a fellow and member of the Council of the American Association for the Advancement of Science (AAAS) Committeeman-at-large, Section on Industrial Science.

STATEMENT OF DR. ROBERT U. AYRES, VICE PRESIDENT, INTERNATIONAL RESEARCH & TECHNOLOGY CORP.

Dr. AYRES. My name is Robert Ayres. I am vice president of International Research & Technology Corp. of Arlington, Va. Over the past 7 years I have conducted three major and several minor studies of automotive propulsion technology. I think I conducted one of the Government studies that was mentioned. The first of these large studies led to the publication of a book, entitled "Alternatives to the Internal Combustion Engine," published by Johns Hopkins University Press in 1972. The second, under the auspicies of the U.S. Department of Transportation is available through the NTIS, and the executive summary has been published and is attached herewith.

It is my understanding that, in the context of examining the pro's and con's of the specific bill under consideration, H.R. 10392, the committee wishes to review the present status of alternative vehicular powerplants. I will address this issue specifically, inasmuch as I have no strong opinions with respect to which agency of the Federal Government should undertake the necessary R. & D. on automotive powerplants. I would add a parenthetical comment that I think it is desirable to continue the advanced automotive power systems (AAPS) program of EPA. The question then does arise in my mind, and probably yours, as to whether the Congress and/or the executive branch is likely to go on for long allowing two or three agencies to do substantially overlapping kinds of research. That is a question on which, however, I have no resolution to offer. However, I do, most emphatically, believe there is an overriding public interest in this matter and that the automotive industry—as presently constituted in the United States—has little incentive, or will, to develop a major technological alternative to the internal combustion engine.

Let me add, here, that I believe it is premature to judge whether any alternative combustion engines can be developed fast enough to offer clear advantages over the ICE—which, after several decades of status quo, has recently resumed a state of rapid evolution. The best authorities I know outside of Detroit believe that by the mid-1980's an advanced form of stratified charge ICE will achieve at least 30 percent better fuel economy than present-day engines, while simultaneously meeting the most stringent emission standards. This is a hard target for any alternative to shoot at. However, it should not be forgotten that the recent burst of technological activity in this field was entirely due to intervention by the Federal Government.

Mr. BROWN. By that you mean the clean air standards?

Mr. AYRES. Yes; primarily that.

It would not have occurred in a "business-as-usual" environment. Moreover, the relatively optimistic forecast I have just cited is not a guaranteed outcome. In fact, without a continuing threat of competition from alternative powerplants developed under Federal programs such as AAPS (EPA) or the one proposed in this bill, I doubt very much whether the present momentum would be sustained.

What of the longer term future? Automobiles and trucks—as now developed—require liquid hydrocarbon fuels derived from petroleum. We are, unquestionably, facing a major petroleum crunch in the United States during the next few decades. There are not any easy answers. The costs and strategic disadvantages of becoming still more dependent on the Middle East than we are now, are obvious and need no repetition. Synthetic crude oil—"syncrude"—derived from coal or shale can and will unquestionably be developed to some extent, but the potential rate of production from shale, at least, is extremely limited by the aridity of the region and the need for water to compact the voluminous wastes. In situ; that is, underground production methods that might get around this difficulty are undeveloped as yet.

Western U.S. coal deposits, too, while ample in quantity cannot fully replace petroleum as a basic source of liquid hydrocarbon fuels. Economic mining involves colossal surface stripping operations that will have adverse long-term ecological impacts over immense land areas. Large quantities of water—scarce in the Colorado River Basin—would be needed for land restoration operations following known procedures. Moreover, water is required in large quantities as a source of the hydrogen, needed to "liquefy" the coal by hydrogenation. The water would have to be diverted from existing recreational, industrial, or agricultural activities, not to mention international commitments to Mexico.

I don't have to dwell on the likely importance of future food production, or its dependence on water. In summary, the production of synthetic liquid hydrocarbon fuels requires a practical conjunction of large supplies of fresh water along with the necessary coal or shale. In the United States this is a difficult condition to meet. For this reason liquid synthetic hydrocarbon production is likely to be limited in quantity and fairly expensive. My personal feeling is that much of this supply will be needed eventually as a feedstock for petrochemicals, several decades in the future, as the existing domestic reserves of crude oil and natural gas begin to dry up.

For various reasons, as it happens, there is increasing worldwide interest in the long-term development of a "hydrogen economy" in which hydrogen is produced from water—at places where water is plentiful—by an electrolytic or thermochemical—or hybrid of the two—process utilizing either nuclear electricity or nuclear reactor heat. When fission reactors are eventually replaced by fusion reactors burning deuterium—heavy hydrogen—from the oceans, it can be seen that synthetic hydrogen or synthetic methane is an attractive method of distributing the resulting energy. In fact, the cost of distributing hydrogen is on the order of one-eighth of the cost of distributing electricity to deliver the same amount of energy. Obviously, the existing network of gas pipelines would be used, and the large existing investment in gas-fueled appliances would not become obsolete.

The alternative long-term solution appears to be to scrap the existing gas-distribution system and to electrify every aspect of our economy, including transportation. Many people assume we have already made this choice in effect, and that the electric car is a long-term answer to our transportation needs. I do not, however, believe that we are irrevocally committed to this path as yet.

With regard to automobiles and automotive transportation, therefore, the future choice in the year 2000 or beyond, seems to be between gas and electricity, with liquid hydrocarbon fuels likely to be relatively scarce. The problems associated with developing and implementing a practical and economical "electric car" have been discussed elsewhere at length. My own conclusion is that, while it is probably technically feasible, a fully electrified automobile-based transportation system in the present pattern is not a practical possibility. The mobile electrical storage systems that would be required to provide reasonable range and performance for vehicles are likely to be intrinsically too expensive and/or short lived. The electrical distribution and "recharge" systems would also be enormously expensive. Problems associated with maintenance and repair of electrical vehicles are also immense, in that it would be necessary to scrap the existing service network and create a completely new one. It is not an exaggeration to say that the present industrial economy would be drastically changed and restructured throughout. The pathway from "here" to "there" seems fraught with obstacles.

On the other hand, consider the use of synthetic gas—say, hydrogen—as an automotive fuel. It would be burned in an engine, like gasoline or other liquid fuels by relatively minor engine and carburetor redesign. It is not hard to envision a car designed to store enough hydrogen for amodes "in city" range—say 30 miles, which would suffice for 80 or 90 percent of all automobile trips today, and perhaps 75 percent of car mileage in the cities. Hopefully the hydrogen storage system—probably a metallic hydride suspension—could be easily "recharged" at night by tapping the local gas distribution network, without requiring special home compressors or other elaborate devices. For longer trips outside the city the driver would fill up an auxillary tank with liquid fuel from a conventional service station. This would, of course, be more expensive.

It is worth noting that hydrogen is the "cleanest" of all fuels and the above scheme insures that most city driving would be done using this fuel. Most important, the path from "here" to "there" is relatively straightforward. Any engine capable of burning either a liquid or gaseous fuel, at will, is acceptable in principle. The stratified charge ICE is not excluded, nor are the Rankine cycle, the Stirling cycle, or Brayton cycle alternatives that are now under development. As between the latter, I believe that none can be ruled out on present evidence as clearly inferior, nor can any be picked as "best," even for a specified application, notwithstanding the comments that have been made by previous witnesses, both today and on previous days. It is of some interest that, although a number of witnesses have been willing to state a clear order of preference of the alternatives, they have stated different orders of preference. I think one must conclude that we don't, in fact, have all the necessary information to make a choice at

this time that would be acceptable to all the experts. This is precisely the major task for R. & D., to undertake in the next decade.

I would like to add one further point; namely, that the most promising means of achieving the desired objective of the bill, that is, fuel economy, is to reduce the weight of the car by substituting later materials and alternative design. Aluminum, magnesium, titanium, and plastics can and will be used for various components in an automobile. The amounts of such materials that are being used is constantly rising as time goes on. And no doubt under the lash of energy shortages, it will rise more rapidly. Newer and lighter materials and designs could be introduced faster still if R. & D. were undertaken and if the automobile industry were prodded in this direction by the Federal Government.

It is true, of course, that some of these materials require much larger investment of energy at the point of manufacture than equivalent amounts of carbon steel. Aluminum, for example, requires several times as much, perhaps 10 times as much energy at the point of manufacture than a piece of steel that will do a similar job. Still, the savings in weight is such that, over the lifetime of an automobile in normal use, there will be a savings amounting to 5–10 times as much as the extra energy that you use at the point of manufacture. Thus, I would say that more attention should be devoted to savings that are available by this strategy in addition to what can be done by modifying the propulsion system.

That completes my prepared testimony.

I would like to add one or two comments on things that have been said today.

First of all, I think I am aware of all the Government studies, but I would not agree that "they all agree" that the gas turbine is the optimum solution.

It is true that the automobile industry itself has said that consistently for years. Some Government and National Academy of Sciences studies reflect the automobile industry view. But the very fact that EPA has spent somewhat more of its money to date developing the Rankine cycle in the advanced automotive power system division, than on gas turbines, is an indication that unanimous agreement does not yet exist as to the optimum solution.

Second, on the question of theoretical limits that has been raised a number of times with respect to the Rankine cycle, I think Mr. Carter gave two reasons why the criterion of theoretical thermodynamic efficiency limits alone doesn't settle the question.

I would add a third reason. Apart from thermodynamics there are also theoretical mechanical considerations. The question of how closely one can approach the theoretical thermodynamic limits has to do with difficulties of mechanical design. There are two contrasting situations which may explain what I am getting at here. In a gas turbine, the net output is the difference between two large numbers, that is, the difference between the work done by the turbo expander minus the work required to operate the compressor. Typically, each net horsepower produced by a gas turbine requires a 3-horsepower expander output and a 2-horsepower compressor input, or 5-horsepower in all. Obviously very high temperatures and speeds, and close tolerances are required. The practical consequences of trying to put all this in a small package that

can be fitted in an automobile and mass produced, are such that it costs many hundreds of millions of dollars to do the engineering development work. Such engines also require very high temperature alloys, very high precision manufacturing techniques, and so on. And the problem of testing components and engines is also very expensive.

In the case of the Rankine cycle engine, you have almost the opposite situation. The net power output is, as before, the difference between the work done by the expander less than the work done by the compressor. But the compression work required in the steam engine is extremely small, because it is done on a liquid, which is almost incompressible. Thus, the actual work done in compression is very nearly zero, and a net output of 1 horsepower requires only a small fraction of 1 horsepower to operate the compresor—which means the expander itself need only produce a little more than 1 horsepower. It is much easier to develop mechanical components for an engine like this, and both development and manufacturing costs are likely to be less. This is why you can't assume, as a rule of thumb, that one can always reach a given fraction of theoretical efficiency for a given level of development effort for any kind of an engine. It isn't true. In fact, one can achieve a much higher fraction of theoretical efficiency in the steam engine (Rankin cycle) as against the gas turbine, for a given amount of R. & D. expenditure. The example of the Carters illustrates that an R. & D. effect undertaken by a small number of people in a very few years was able to achieve an efficiency level comparable to what the ICE or the gas turbine have achieved with much higher levels of expenditure over several decades.

I am willing to answer any questions you have.

Mr. Brown. Thank you very much, Dr. Ayres. I note your published paper attached to your statement; and without objection, that will be included in the record, also.

economic impact of mass production of alternative low emission automotive power systems

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The study considers a range of possible effects on the transportation industry, satellite industries, the labor market, and the economy which may be anticipated in the event mass production of unconventional low emission automotive propulsion systems should occur, whether as a consequence of federal intervention, or not. A postulated 1976 Otto Cycle Internal Combustion Engine equipped with a dual catalyst manifold reactor and other "conventional" emission control devices was compared in detail with a Regenerative Free Turbine Engine and a Rankine Cycle Engine, as specified by the contracting agency. Manufacturing costs, operating and ownership costs, consumer demand, inter-industry effects, employment, resource requirements, and international trade implications were analyzed in depth under a number of plausible sets of policy constraints and parametric variations. Principal conclusions are that conversion over a 10 year period is feasible, that manufacturing cost differentials are less critical than fuel consumption and cost differentials, that industry/employment impacts are minor, and that resource/trade effects are dominated by petroleum imports. Implications for federal policy are discussed.

Although the Congress has mandated a set of emission standards to be met in the years 1975–76 (or 1976–77 in case the *Administrator of the Environmental Protection Agency* permits a one year delay under the terms of the legislation), it cannot be taken for granted that the automobile manufacturers will be successful in developing the requisite emissions control technology along the lines currently envisaged. In the event of their failure to do so, it is conceivable the Federal Government would put heavy pressure on the industry to introduce an alternative "nonpolluting" form of vehicular power plant. The study summarized here was undertaken to provide an initial assessment of the socioeconomic impact of such *a conversion, whether brought about by external federal pressure* or as a result of intra-industry competitive forces.

Scope and Assumptions of the Study

The "scenario" underlying the study involves a conversion from the presently used spark ignition Otto-Cycle (OC) engine or any of several reduced emission versions to one of two prespecified Low Emissions Alternative (LEA) power plants. The emissions controlled variants of the OC engine considered in the study were specified by the Environmental Protection Agency at the beginning of the study in July 1971. There have been a number of developments in emissions control technology which might affect the conclusions to a modest degree, but, *apart from simple recognition that the Otto Cycle* Engine is a "moving target," such recent developments are not included in the terms of reference of the study. By directive from the Department of Transportation, the alternative engines initially considered were (1) a hypothetical regenerative free turbine (RFT) similar, but not identical, to

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automotive gas turbines developed by Chrysler Corporation and Williams Research Corporation among others, and (2) several alternate designs of a hypothetical Rankine Cycle Engine (RCE) based on design studies and component development carried out by Thermo Electron Corporation (TECO) under contract to the Environmental Protection Agency. A list of the design variants considered follows. It must be emphasized that these variant power plants were selected as representatives of classes of engines, but that the specific design configurations chosen for the study did not result from extensive optimization studies. On the contrary, the choice was primarily determined by the availability of fairly detailed engineering level information, without which the economic analysis could not have been undertaken.

Case designations used throughout the report are as follows:

- OC(1) OC-70 plus the Exhaust Gas Recirculator (EGR)
- OC(2) As above plus Dual Catalytic Convertor and miscellaneous (no change in engine size)
- OC(3) Similar to OC(2) plus 400 cubic inch engine
- OC(4) Similar to OC(3) plus Exhaust Manifold Reactor (EMR)
  Detailed descriptions of emission control devices may be found in the report (Chapter 2).
- RFT(1) Conventional regenerative gas turbine, with superalloy burner parts and ceramic (alumina) rotary regenerator
- RFT(2) RFT(1) with ceramic burner parts and ceramic (alumina) regenerator
- RFT(3) RFT(1) with superalloy burner parts, with a stainless steel regenerator
- RFT(4) RFT(1) with ceramic burner parts, with a stainless steel regenerator
- RCE(1) Conventional cylindrical burner-boiler design using high cobalt superalloy (U-500); proprietary TECO valve design
- RCE(2) Revised burner using low cobalt superalloy (Hastelloy X)
- RCE(3) Revised toroidal burner-boiler design, using low-cobalt alloy
- RCE(4) New valve by BICERI† replacing TECO valve; no transmission
- RCE(5) Combination of RCE(3) and RCE(4)

It is extremely important to reiterate that there exist a number of plausible alternative power plants that were not specifically analyzed in the study. There are recent indications, for instance, that some pollution control devices or approaches not considered in the report may prove superior to those which were specified. The Wankel engine with thermal reactors offers some possibilities, as does the lightweight Diesel, the "stratified charge" engine, and the electronic fuel injection with emissions control feedback. Similarly, there are a number of radically different but as yet untested gas turbine concepts seemingly worthy of serious investigation. With regard to external combustion engines, one must keep in mind the possibility of technological breakthroughs in the area of combustor-burners, organic working fluids, lubricants, and antifreeze enhancing the use of water-steam, or even closed cycle organic turbines. The Stirling cycle engine cannot be excluded from consideration.

It is also important, in understanding the significance of the results of the study, to emphasize that the OCE is a highly evolved real engine, and the reduced emissions variants are relatively straightforward extrapolations involving few uncertainties except in regard to emissions control equipment performance and cost. On the other hand, the alternative engines, as such, exist only on paper or in the laboratory, although separate components and similar engines have been built and tested. In this respect, the gas turbine is more advanced than the Rankine cycle engine. However, neither of the alternative designs have undergone the same degree of evolutionary refinement, suboptimization, and proliferation of variants as the Otto cycle engine. Hence, conclusions about both performance characteristics and costs are also considerably more uncertain, and the range of possible error in determining performance capabilities is greater for LEA engines. There is also, by the same token, more scope for future improvement and cost reduction in the latter because they are less technologically mature.

Under the imposed ground rules of the study, two alternative conversion schedules, four years and ten years, were considered. The results of the study lead to the conclusion that a 4 year conversion is not feasible if all pre-production engineering and testing phases are included. These activities will require a minimum of 6–7 years if pre-production consumer testing is included, and 4-5 years if it is not. Once production begins, a four year conversion of the engine manufacturing industry appears feasible. On the other hand, a 10 year period for conversion of production facilities *per se* seems excessive, since it would impose a heavy burden of maintaining dual facilities and inventory on the service and repair sectors without substantially increasing the salvage value of existing engine production capital equipment. The main advantage of the longer period would be to facilitate retraining repair and maintenance personnel. Hence, an overall 10-year (6-year pre-production and 4-year production) conversion scenario is considered to be optimal. Both short-term adjustment problems and longer-term economic shifts resulting from the conversion are analyzed in the following report.

Another ground rule of the study is that only standard size automobiles are considered. In fact, the baseline vehicle is a six passenger sedan of 4000 lb curb weight with a 300 cu in. V-8 engine, equipped with automatic transmission and air-conditioning and producing a maximum of 150 horsepower at the rear wheels.‡ This engine was designated as the OC-70. Alternative power plants, including the emission-controlled versions of the Otto cycle engine, were sized to produce comparable acceleration and performance characteristics. Thus, all power plants are assumed to be equivalent in performance, just as they are assumed to be equivalent in emissions—at least to the extent of meeting the proposed 1976 standards. While the latter assumption is obviously somewhat questionable, any differences between the engines, in terms of pollution, were defined as being outside the scope of the study.

Some other assumptions have been made in the computational part of the study. One critical assumption, based upon the latest information compiled by the National Academy of Sciences Committee on Motor Vehicle Emissions, is that the addition of an Exhaust Gas Recirculation (EGR) System and a Dual Catalytic Convertor to the OC-70 will result in a 25% increase in fuel consumption, or (equivalently) a 20% loss in fuel economy for the 1976 Otto-Cycle Engine, OC(2), OC(4) or OC(5).

"Structural" assumptions are, in brief, that a free market exists in the motor vehicle and related industries, at least to the extent that firms choose strategies which tend to minimize net costs and maximize return on investment. It is assumed that some economies of scale exist in production (up to a level of perhaps 500,000 units/yr) but that the classic intercept of rising-cost versus falling demand curves determines the quantity sold to consumers. This ensures that increased car prices will have some adverse impact on sales (and employment) of the auto industry.

On a detailed level, there are a great number of assumptions

† BICERI = British Internal Combustion Engine Research Institute, Ltd.

‡ Nominal horsepower may be considerably larger.

with regard to the validity of specific equations or quantitative choices of parameters. These have been dealt with in two ways:

(1) With each parameter, a range of uncertainty as to its true value has been estimated, and, for each output variable, a resulting variance has been computed. The percentage contribution to the total variance of the output by the individual parameter uncertainties have also been computed. Thus the interested reader can judge quantitatively the importance of any given parametric assumption.

(2) A complete self-consistent set of results for each of a number of specific parametric variations or "scenarios," in addition to one standard case, have also been computed. Alternative assumptions have been explored for corporate income taxes, investment tax credits, depreciation rates, return on investment, wage rates, vehicle weight, and safety requirements and other factors affecting manufacturing costs. Consumer cost factors were varied explicitly; they include basic fuel cost, fuel consumption (by engine), driving cycle—urban, suburban, rural, composite—maintenance and repair cost, and depreciation rate for used cars. (Lifetime in years and lifetime vehicle mileage are directly related to the latter parameter.)

The flow of information in the report is as follows. In brief, the manufacturing cost, capital requirements, and interindustry flow of materials (including fuel) and components are estimated on the basis of an engineering level analysis of each of the basic engine types. Impact on consumers is based on purchased price, fuel consumption and price, and repair and maintenance requirements derived from the engineering analysis. The material and dollar flows are also adjusted for changes in the number of automobiles sold, based on calculated prices. Employment effects are estimated by assuming labor requirements are proportional to industry output. Indirect waste output, overall raw materials requirements, and foreign trade effects are also calculated on the basis of the various interindustry dollar and material flows.

To avoid too specific commercial implications, the analysis is based on aggregated census Standard Industrial Classification (SIC) definitions of industries rather than attempting to identify likely effects on specific firms. It should be emphasized that the Census categories are based on "establishments" (i.e., individual factories) rather than organizations. Thus, various divisions of a given firm may easily belong to several different "industries," and industries as classified by the Census do not necessarily correspond with company lines or divisions.

Results

Results of the study are of three general kinds:

(1) Statements of a structural sort, having application beyond the specific engine alternatives discussed in the report, reflecting aspects of the manufacturing process, inter-industry relationships, supply-demand relationships, resource constraints, technological possibilities, and interfaces between government, industry, and consumers.
(2) Statements of a quantitative kind, mainly having to do with comparisons between specific engine alternatives or sensitivity of the analysis to parametric variation.
(3) Statement of conclusions relevant to policy options.

In many ways, the most interesting and important results of the study are those in the first category, even though in many cases they are judgments and not rigorous conclusions derivable from quantitative analysis as such, but rather by synthesis of the entire range of information—including both exogenous (input) and endogenous (computed) data—assembled for and generated by this study.

General Conclusions

(1) A major technological change in the automobile power plant could be accomplished within a decade, from start to finish, without serious economic upheaval, though probably not without government intervention (at least in the sense of defining emission or safety standards or other constraints within which the industry must operate). A significantly shorter conversion period would be an invitation to serious economic dislocation since it would not allow time to develop and "debug" the new product, as well as the associated production line equipment and downstream maintenance and repair facilities (including labor retraining). In any mishap of this kind, consumers and the general public would be major losers.

(2) The economic sectors most strongly affected over the long run by a technological change in automotive power plants are petroleum refining and fuel distribution. A switch from the standard engine (OC-70) to an emission-controlled version involves a major change in refining processes to eliminate tetraethyl lead and upgrade the pool of (unleaded) gasoline from its current average level of 88.5 octane to at least 91 octane, while also increasing production significantly. During the transition, higher octane (leaded) fuels will still be needed for older cars still on the road—no problem for the refiners but a problem for the distributors since many gasoline retailers currently only have facilities for two grades of fuel. For this reason, it is likely that unleaded gasoline will be produced at 93 or 94 octane rather than 91 octane, to eliminate the need for 94 octane "regular" gasoline. Conversion to an RFT or RCE would compound this difficulty by adding a third (or fourth) grade of distillate fuel similar to diesel. Again, there is no problem in converting the refineries over a period of 10–15 years. However, in all likelihood, it will be infeasible for most retailers to handle all three (or four) grades of fuel, and some transitional allocation problems can be expected.

(3) Automobile engines account for significant fractions of the world output of some materials. It would therefore appear that for technological changes involving additional uses of metals other than steel, aluminum, copper, zinc, and lead, for which world markets are large, time may have to be allowed after the production prototype is determined to secure reliable long-term sources of supply. (This may, in some cases, involve opening new mines or new ore refining facilities.)

(4) It can be expected that any increase in the manufacturing cost of the engine will be passed on to consumers. However, even a sizable increase in power plant costs has a relatively small impact on overall vehicle prices. For a standard-sized sedan, doubling the cost of the power plant would add only about $430, or 12%, to the retail price of the car to the consumer.

(5) The initial purchase price of the car, plus finance charges, represents only a fraction of overall costs of vehicle ownership and operation. This fraction is by far the greatest for new car buyers (about 50% in the first year), declining rapidly to about 25% in the 4th year and to no more than 15% in the 7th year. Thus, a 12% increase in new car prices (which might result from a 100% increase in engine manufacturing cost) adds about 6% to the first year costs of an owner-operator, but only 3% to the 4th year costs, and 1.8% to the 7th year costs.

(6) The impact of fuel costs and fuel taxes on users is roughly comparable to the impact of depreciation and finance charges, over the life of a car. In the first year, depreciation typically outweighs fuel costs by a ratio of 2:1, but by the 4th or 5th year, the two are about equal, and after the 7th year the ratio is reversed. In fact, fuel accounts for roughly 25 to 30% of all costs of ownership and operation throughout the life of the vehicle, roughly equal to depreciation and finance charges. Hence, a 25% increase in fuel consumption per vehicle mile,* or a comparable increase in fuel prices per gallon, will have the same average effect as a 25%

* Such as might result from emissions controls contemplated for the Otto Cycle engine.

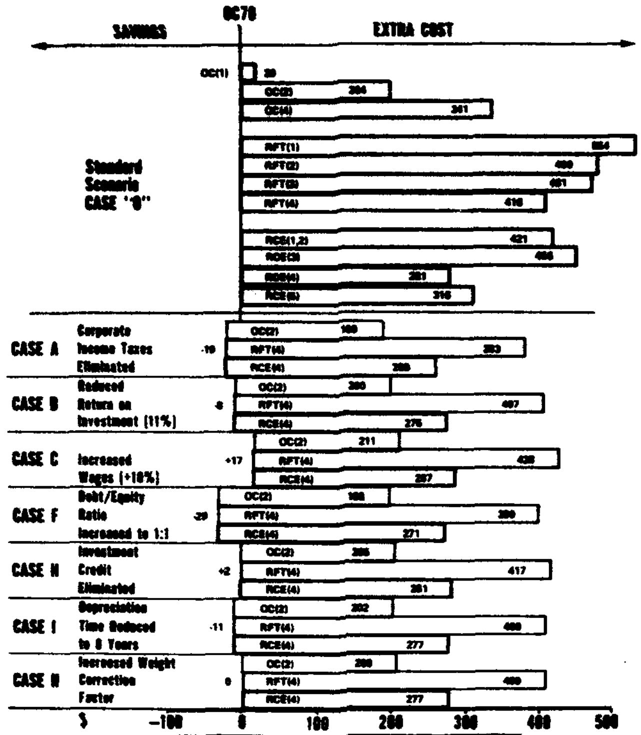

Figure 1. Initial price increase/decrease relative to OC-70.

increase in new car prices. However, the impact ultimately will be relatively greater on the drivers of older cars, who presumably represent lower income groups. Thus, in any tradeoff between raising new car prices and raising fuel consumption per mile traveled or fuel costs per gallon, a decision to minimize car price increases at the expense of permitting fuel consumption or price increases will tend to be regressive in its socio-economic impact.

(7) Because there are only very limited opportunities for substitution in the realm of personal transportation, increased automobile prices—from any cause—have a relatively slight effect on auto sales, if we disregard short-term transient effects. Typically, a 10% price increase (spread over several years) would result in only a 3.5% decline in dollar sales, on an equilibrium basis, or $1.7 billion for the projected 1980 sales volume.

(8) Sudden sharp increases in price do tend to exaggerate the long-term adverse effect on sales and result in losses that are never made up. Temporary sales losses to an industry as large as the auto industry are felt at the level of the economy as a whole. That is, the auto industry's short-term loss is not translated into some other sector(s) gain, but rather it results in a net drop in industrial output, employment, personal income, and GNP. This can be avoided through government-industry cooperation to ensure a gradualist approach to price changes.

(9) The capital resources available to the automobile manufacturing industry, either through internal redirection, e.g., deferral of annual model changes, or through external sources, appears ample to finance conversion to an alternative type of power plant. In fact, the total capital investment in engine facilities for the most expensive alternative considered is roughly the same as a single year's current capital expenditures by the motor vehicle industry. (It may be noted, in passing, that the industry price leader, GM, currently makes no use of borrowed funds, even though it appears that greater use of debt financing could significantly increase earnings or cut prices.)

(10) While there would appear to be little or no financial risk to the automobile industry in undertaking a major technological conversion mandated by the government, if the choice of technology and the conversion scheduling were carried out independently of the government, with different firms selecting different conversion paths, the risks appear to be significant. Thus, it seems that the industry has a very strong incentive to obtain the widest possible consensus on the optimum technological choice prior to undertaking any major investment commitments. Past industry reluctance to admit even the possibility of any serious alternative to the Otto Cycle Engine (OCE)—with industry R&D tending to focus on rather exotic long-term possibilities such as the sodium-sulfur battery—should be viewed in the light of this

circumstance. Notwithstanding the above remarks, it is not suggested that a government mandate of a specific technology is desirable. On the contrary, it may well be preferable from a public interest standpoint to encourage risk-taking in the private sector.

(11) To the extent that there is any choice between using imported (and costly) metals (e.g., nickel, chrome, cobalt) to reduce fuel consumption versus using more fuel in an engine requiring cheaper materials, balance-of-trade as well as energy-conservation considerations would dictate minimizing fuel consumption rather than engine price. The impact of the auto industry on international trade occurs in three areas: basic materials (metals and ores), petroleum, and motor vehicles and parts. Conversion of the auto industry to an alternative technology would have no *a priori* effect on the third of these, although if prices rise sharply, sales of small subcompact cars—now mostly imported—are likely to increase at the expense of larger cars. On the other hand, it seems likely that conversion to an LEA engine would constitute a significant non-tariff barrier to imports of foreign cars. Both metals and petroleum are increasingly imported, but the impact on balance of payments is overwhelmingly dominated by petroleum. It may be noted that the above conclusion is "new." That is, the choice would almost certainly have gone the other way a decade or two ago when the U. S. balance of payments was favorable.

Quantitative Conclusions

In this section, the alternative power plant design options and parametric variations are specifically compared with respect to manufacturing costs, fuel requirements and costs, consumers costs, demand for motor vehicles, impact on industry and employment, material requirements, and trade.

Engine Manufacturing

For the OC-70, an independent estimate of plant machine tools and production line equipment was made for a hypothetical engine plant of 10^6 units per year capacity* producing 350 cu in. V-8 engines. Capital investment per unit (capacity) was estimated to be $271. Total production labor per engine was estimated on the basis of data supplied to the United Auto Workers (UAW) by Chrysler Corporation; average wages per man-year, including benefits and overtime being derived from the same source.

Manufacturing costs for emission control devices applicable to the OC(1), OC(2), and OC(4) were obtained partly from the National Academy of Sciences Committee on Motor Vehicle Emissions. In a few cases, there were differences, but these differences have relatively little impact on the results.

Costs for the two alternative engine types (RFT and RCE) were derived by estimating direct manufacturing costs and direct production labor. The basic data came from vendors and parts suppliers, and from engineering costing analysis done by the manufacturing subsidiaries of the United Aircraft Corporation.† A cost model was then constructed to reconcile the different types of data sources and ensure reasonable consistency between estimates for different engine types. Direct production labor was uniformly defined as labor "touching" a material or component (i.e., operating production-line machines), while indirect production labor was defined as all other labor involved in providing engineering services, utility services, transportation and warehousing, maintenance, tool-making, and so forth. "Indirect" overhead was defined as administrative, financial, legal, sales, R&D, etc. Indirect production labor was taken to be a fixed ratio to direct production labor (based on OC-70 data) while indirect overhead was assumed to be unaffected by engine design. Costs of equity and *debt financing*, and the impact of taxes, tax credits, interest deductions, and depreciation allowances were computed by standard methods.

Overall costs were estimated and broken down to display the contribution of various cost elements for all twelve variant engine designs for the standard assumptions (i.e., best estimates of relevant parameters). There was a clear advantage in terms of costs for the OC(2) as compared to the OC(4) and for the RFT(4) and RCE(4) variants, respectively. These cases were then selected as the basis for all further quantitative comparisons.

Materials (direct and indirect) account for the largest single fraction of engine cost for all engines studied, ranging from a low of 47% for the OC-70 to 53% for the OC(2), 55% for the RFT(4), and 58% for the RCE(4). Direct and indirect labor is the next largest cost component, accounting for 36, 30, 29, and 26% respectively for the four engines. Capital—both fixed and working—and taxes account for between 16 and 17% for all engines. The main result, of course, is that the OC(2) will result in a price increase to consumers of about $205. Price increases for the RFT(4) would be about $415, and for the RCE(4) the differential would be $280. A summary of the key production cost data is given in Table I.

The sensitivity of these results to alternative assumptions is displayed in Figure 1. The principal conclusion to be drawn is that both the rank ordering of the four engines and the magnitudes of the differentials are largely unaffected by altering the parameters within reasonable ranges.

Table I. Summary of selected results.

Fuel requirements	OC-Engine Case OC-70 97 Octane lead[a]	OC-Engine Case OC(2) 91 Octane no-lead	Standard turbine engine Case RFT(4) Middle distillates	Standard Rankine cycle engine Case RCE(4) Middle distillates
Fuel cost/gal (excluding taxes)	0.23	0.225	0.205	0.205
Fuel economy (mpg)	11.4	9.1	12.4	12.2
Engine weight increment (lb/engine)	0	+72	−121	+474
Engine direct mfg. cost ($)	$282	$321	$444	$357
Engine cost to consumers ($)				
Direct labor in engine production (man-yr/10^6 units)	3940	5775	8896	4865
Direct labor in man-hr/engine	7.88	11.55	17.79	9.73
Capital investment ($/unit) in engine production facilities	$271	$313	$395	$340
Lifetime engine-related repair and maintenance ($)	1148	1832	1791	1245

[a] The average 1970 engine requires a 93 octane fuel which would be slightly less costly than the 91 octane unleaded fuel. Regrettably, many people use premium fuel unnecessarily—the average rating being close to 97 octane.

Table II. Fuel consumption over simulated duty cycles.

	OC-70	OC(2)	RFT(4)	RCE(4)
Federal driving cycle (urban)	9.49	7.59	9.36	10.95
Suburban cycle	12.7	10.2	13.3	15.4
Rural cycle	12.5	10.0	15.5	11.6
Composite cycle	11.4	9.1	12.2	12.4

* Actual plants are not this big, but costs per unit are expected to be the same, since economies of scale in engine manufacturing appear to reach a limit of about 500,000 units per year.
† Parent of United Aircraft Research Laboratories, a subcontractor on this study.

Table III. Summary of ownership and operating costs, nth year.

	Otto cycle		Gas turbine	Rankine cycle
	OC-70	OC(2)	RFT(4)	RCE(4)
1st year costs				
Depreciation	882.24	938.78	997.42	960.00
Interest	134.04	143.70	152.67	146.96
Fuel	363.07	432.69	294.06	289.31
Fuel taxes	168.86	211.54	157.79	156.24
Garage, parking, toll	315.00	315.00	315.00	315.00
Eng. maintenance and repair	57.40	91.60	80.56	62.50
Other maintenance and repairs	37.50	37.50	37.50	37.50
Insurance	128.00	128.00	128.00	128.00
TOTAL	2067.10	2298.80	2172.00	2094.50
4th year costs				
Depreciation	333.43	354.80	376.96	362.91
Interest	50.64	53.89	57.25	55.10
Fuel	242.11	296.70	201.64	198.39
Fuel taxes	115.79	145.05	108.20	106.45
Garage, parking, toll	216.00	216.00	216.00	216.00
Eng. maintenance and repair	149.24	238.16	232.83	161.85
Other maintenance and repairs	97.50	97.50	97.50	97.50
Insurance	124.00	124.00	124.00	124.00
TOTAL	1328.70	1526.10	1414.40	1322.20
7th year costs				
Depreciation	126.01	134.09	142.46	137.12
Interest	6.75	7.18	7.63	7.85
Fuel	155.35	190.38	129.39	127.30
Fuel taxes	74.30	93.08	69.43	68.31
Garage, parking, toll	138.60	138.60	138.60	138.60
Eng. maintenance and repair	137.76	219.84	214.92	149.40
Other maintenance and repair	90.00	90.00	90.00	90.00
Insurance	118.00	118.00	118.00	118.00
TOTAL	846.80	991.20	910.40	836.10
Discounted* totals,				
Years 1–3	3771.4	4212.9	3954.1	3785.8
Years 4–6	2418.3	2804.0	2597.7	2405.0
Years 7–10	1879.5	2178.9	1966.2	1832.1

* 10% annual rate.

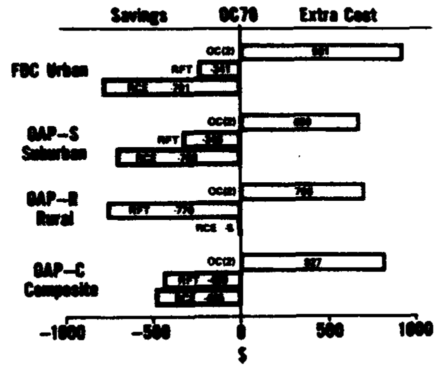

Figure 2. Lifetime fuel costs/savings relative to OC-70.

Fuel Consumption and Costs

Fuel consumption for each engine has been estimated for four different simulated "duty cycles" representing various conditions. The Federal Driving Cycle (FDC) is a rather complex sequence of prescribed driver actions used as a basis for EPA automotive emissions tests. It was designed to approximately reproduce urban driving conditions. The Office of Air Programs (OAP) at EPA has also designed a simulated "suburban" cycle, a simulated "rural" cycle—mostly high speed cruising—and a "composite" cycle roughly representative of the national average.

If engine fuel consumption is known as a function of traction load (torque) and speed (RPM), fuel consumption for any simulated set of driving conditions can be calculated on a computer. This has been done for the OC-70 as well as for the two "paper" engines, the RFT and RCE. As noted earlier, the fuel consumption for the OC(2) or for the OC(4) are simply assumed to be 25% greater than for the OC-70.* For the given OC-70 (4000 lb curb weight with automatic transmission and air conditioning), the calculated fuel economy is 9.49 mpg on the Federal Driving Cycle. It can be shown that this figure is consistent with EPA test data for vehicles of comparable weight, similarly equipped.† Based on available engineering performance data on the alternative engines, computer simulations have also been carried out for the other engines, leading to the results shown in Table II.

Fuel requirements vary considerably. The OC-70 is presumed to utilize leaded gasoline having an "average" octane rating of 97‡ and costing 23¢ per gallon exclusive of 11¢ taxes. The OC(2) or OC(94) could utilize a 91 octane non-leaded fuel costing about 22.5¢ per gallon; however, to minimize distribution problems, a 93 or 94 octane non-leaded gasoline may be sold in place of existing "regular" grades. This would cost anywhere from 0.2¢ to 0.9¢/gal more than existing (97 octane) fuel. On the other hand, either the RFT or RCE could utilize distillate fuels. The latter could be produced at a savings of at least 2.5¢/gal compared to present grades.

Fuel costs to consumers depend upon (1) the mileage driven; (2) the duty cycle (urban, suburban, rural, etc.); (3) the basic fuel consumption of the engine; and (4) the price of fuel per gallon (including State and Federal taxes). The national average for all passenger cars on the road was about 9900 miles per car in 1971. However, this is an average over cars of all ages. When age is taken into account, however, there is considerable variation: from 17,500 mi/yr in the first year to around 6000 miles in the tenth year of operation. The median lifetime of all cars is about 9.5 years, but some cars continue to operate for 15 or more years, so the "average" mileage per year continues to be non-zero even after the tenth year. Lifetime mileage appears to be about 112,000 miles.

Based on the above framework, it is possible to compute expected fuel costs (including taxes) on an annual basis and over the life of a car. Here there are quite dramatic differences, depending on the parametric assumptions, as shown in Figure 2. Both the RFT(4) and RCE(4) exhibit significant cost advantages over the OC(2), if the standard case assumptions with regard to fuel economy and cost are accurate. There are important differences, however, between the urban and rural cycles. On an urban driving cycle, the RCE(4) appears to offer significant advantages even with respect to the OC-70; whereas on a rural cycle, the RFT(4) is favored. The difference between either the RFT(4) or the RCE(4) and the OC(2) in the standard case for a composite (national average) duty cycle is 40%. Thus, even if we assume that fuel economy for the OC(2) has been underestimated by 15% (i.e., we assume there is only a 5% penalty for emission control devices on the OC(2) vis à vis the OC-70) the LEA engines still offer roughly 10% lower lifetime fuel costs to the consumer. This appears to be one of the most significant results of the study.

* Hence, the fuel economy of the OC(2) or OC(4) is 20% less than for the OC-70.

† An automobile of 4000 lb curb weight is defined as 4300 lb test weight, which corresponds to 4500 lb inertial weight. The air conditioning subtracts 9% from measured fuel economy over the Federal Driving Cycle.

‡ Although 94 octane is theoretically adequate for the OC-70, consumers tend to overbuy premium grades of fuel.

Sensitivity of Consumer Impact to Alternate Assumptions

Apart from fuel, the costs of owning and operating an automobile are attributable to depreciation and finance charges (interest), repair and maintenance, insurance, parking, tolls, and registration. Depreciation and repair costs are primarily a function of the age of the car; parking and tolls are proportional to mileage, whereas the other costs tend to be relatively constant. The major cost elements including fuel are tabulated in Table III and plotted versus vehicle age in Figure 3. One important implication of this, already noted under "structural conclusions," is that any increase in purchase price or fuel consumption would have a disproportionate impact on owners of older cars. The sensitivity of consumer ownership and operating costs to various alternate assumptions is exhibited in Figure 4. The major result is that both LEA engines offer substantially lower overall costs than the OC(2) under almost all circumstances. Of the two LEA engines, the RCE(4) appears to have a significant advantage, which becomes proportionally greater for older cars. While this result is quantitatively dependent on the fuel consumption and fuel cost estimates, even much less favorable assumptions do not appear to alter the qualitative comparisons.

It should be noted that there will be significant differences among the various engines as perceived by vehicle operators. These differences will affect driveability, convenience, and aesthetics. For instance, the OC(2) or OC(4) will require frequent inspections and adjustment—a nuisance to drivers. The RFT engine has a characteristic high pitched whine which might be irritating to some people, especially if acoustic muffling fails in older cars. There is also a perceptible "lag" on acceleration due to the inertia of high-speed turbo-machinery.* Its relative compactness and light weight offer some benefits to the vehicle designer and stylist. It would be the easiest engine to adapt to a small car, for instance. The RCE will probably take a little longer to start cold than the others (45 to 90 sec, depending on outside temperature). It is also somewhat bulky and will constrain the styling possibilities for the car—especially with respect to the front grill. It will be harder to adapt to a very small car than a turbine. *On the other hand*, the RCE may have unusually good driveability characteristics, with rapid smooth acceleration. Since each engine has both advantages and disadvantages, the net impact of these non-cost differences cannot be determined in the absence of consumer testing.

Sensitivity of Demand for Motor Vehicles to Alternate Assumptions

The potential impact of vehicle price increases on demand (i.e., sales) has already been mentioned. The sensitivity of this general result to alternative assumptions is shown by Figure 5. The extra costs associated with 1976 safety requirements will add about $425 to the price of a standard car as compared to the cost of meeting 1976 pollution requirements, $205 for the OC(2), $415 for the RFT(4), and $280 for the RCE(4). Effects on sales will be cumulative. Meeting pollution standards alone would appear to result in a drop in "equilibrium" demand of −1.4, −2.8, and −1.9% respectively. Meeting safety requirements, in addition, will increase these numbers to −4.3% for the OC(2), −5.8% for the RFT(4), and −4.8% for the RCE(4).

Two further points should be made in regard to demand. First, the econometric demand model used in this report is extremely sensitive to assumptions about the depreciation rate of the existing inventory of cars, which is currently 27.7%/yr. If this depreciation rate should drop to 25%/yr, *effective car life would increase* by as much as 3 years, and annual sales of new cars would drop by about 6.7% below

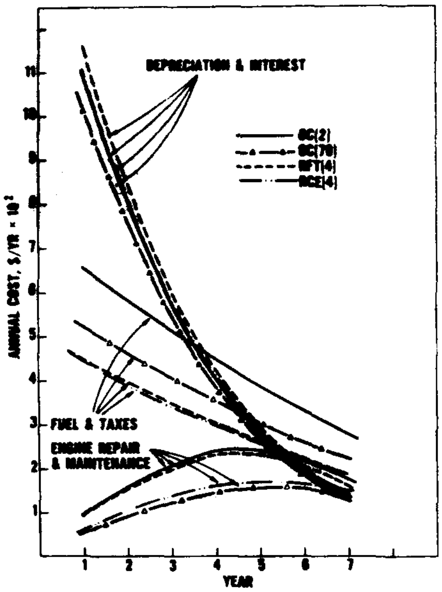

Figure 3. Variation of consumer costs with vehicle age.

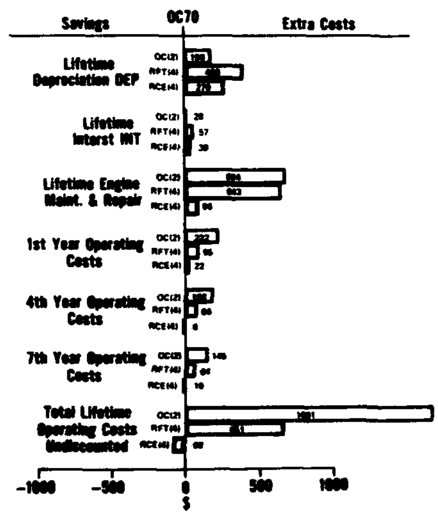

Figure 4. Differential impact of engine choice on consumer costs relative to OC-70.

* Depending on the specifics of transmission and engine design, however.

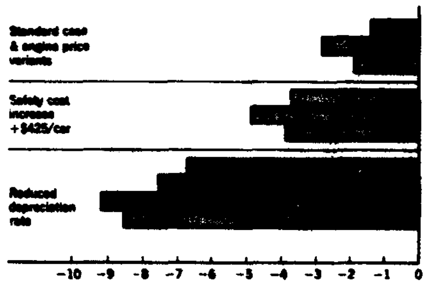

Figure 5. Differential impact of engine choice on demand.

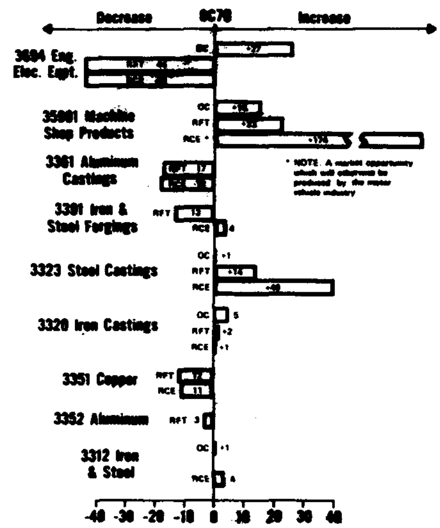

Figure 6. Differential impact of engine choice on industrial sectors.

baseline projections, or $3.2 billion in 1980. Conversely, if the depreciation rate for older vehicles should increase to 30%/yr (the "orphan car" effect), annual sales of new cars in equilibrium would increase by 5.4% over the baseline projection, or $2.6 billion in 1980, other factors remaining equal. It is difficult to forecast which, if either, of these changes might occur in the event of conversion to a LEA engine.

The second qualifying remark is that the demand model that was used does not reflect the effect (if any) of changes in operating costs. One may note, however, that if discounted value (DPV) of all costs for the first three years of a vehicle's life were used as an explanatory variable (in place of purchase price), introduction of the OC(2) would have a more adverse effect on sales than either of the LEA engines. However, this cannot be stated as a definite conclusion, but merely as a plausible hypothesis.

Industry Output and Employment Effects

A summary of the long-term impact on industrial output and employment, by sector, are given in Figure 6. The principal conclusion to be drawn is that even a radical engine redesign would have no major effect on any industry classified by census categories, except in the case of steel castings. However, the magnitude of the apparent impact here is somewhat misleading, since the activities in question would certainly be carried out internally by motor vehicle manufacturers.

Effects on engine electrical equipment suppliers (notably spark plugs and distributors) and machine shop products (notably carburetors and fuel controls) would also be significant, though not catastrophic. Again, much of this production is actually internal to the major automobile manufacturers, which would reduce the impact of change.

Labor inputs for manufacturing all three alternative engines OC(2), RFT(4), and RCE(4) are higher than for the OC-70, as can be seen by comparing labor costs in Table I. Increases with respect to the OC-70 for production labor are as follows: +20% for the OC(2), +54% for the RFT(4), and +11% for the RCE(4). This extra employment does not entirely correspond to a drop in productivity since the consumer receives a higher quality product. However, it should be noted that the environmental benefits of the OC(2), RFT(4), and RCE(4) are presumed to be equal.

Major employment increases are also projected for the repair and maintenance sector in the case of the OC(2) (+13%) and the RFT(4) (+93%), but not for the RCE(4). These estimates are not considered to be the most reliable in the report because of the difficulty of projecting repair and maintenance requirements for "paper" engines. However, sensitivity analysis indicates that different assumptions here will have relatively little impact on the overall cost comparisons between the various engines. The additional repair and maintenance labor needed for the OC(2) and, particularly the RFT(4) as compared with the OC-70 and the RCE(4), should probably be regarded as a net decrease in productivity, if the same environmental quality can be achieved. While additional employment is created, it is not necessarily of a kind that is most desirable from the standpoint of utilising human resources.

State and Federal Highway Tax Revenues

Taxes on fuel are assumed to remain at the present level on a per gallon basis. Compared to the baseline projections, the OC(2) would increase revenues from this source by 25% after conversion of the existing vehicle inventory, while the RFT(4) and RCE(4) would decrease fuel tax revenues by 7% and 9% respectively. If tax rates were to be adjusted to equalise the revenue in all three cases, the tax per gallon would drop by 2.7¢ for OC-70 fuel and increase by .8¢ to 1¢ for the LEA engines.

Resources and Trade

A summary of the impact of alternative engine designs on baseline consumption of a number of key materials, including high temperature metals, catalyst metals, and petroleum are shown in Table IV and Figure 7. The magnitude of the potential impacts has a number of interrelated implications:

1. To increase current levels of output of some relatively scarce metals like platinum and palladium which may require major investments and considerable time, resulting in interim shortages and (perhaps) undesirable dependence on single sources of supply.
2. Even though many of the critical materials are imported, trade effects are overwhelmingly dominated by petroleum.
3. Recycling of scarce metals such as platinum, palladium, tantalum, and tungsten will be a practical necessity, no matter which of the engine alternatives is adopted.

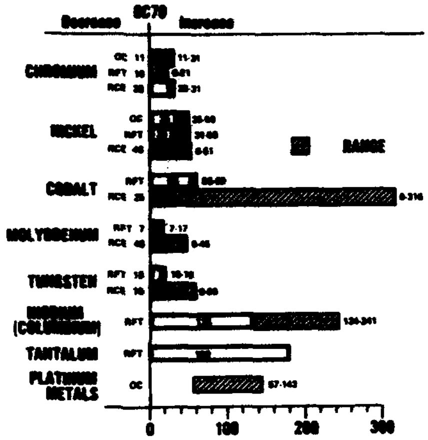

Figure 7. Differential impact of engine choice on resource requirements.

Table IV. Impact due to various engine types. ($ × 10⁶)

Engine type	High-temperature[a] metals		Catalyst[b] metals		Crude[c] oil		Total	
	Low	High	Low	High	Low	High	Low	High
OCE	136	210	86	216	1437	2735	1659	3161
RFT	*157*	*241*			−538	306	−381	547
RCE	27	325			−461	1224	−634	1549

[a] Chromium, nickel, cobalt, tungsten, niobium, tantalum.
[b] 0.08 to 0.2 (Tr oz) per engine; assumed to be half platinum and half palladium.
[c] All increase or decrease is imported.

Policy Implications

There are several major areas where government policy should be developed *to minimize possible adverse impacts* of a vehicular power plant substitution, at least if such a substitution is brought about as a result of Federal intervention. These areas are as follows:

Price Policy. In the event that a technological substitution involves price increases of the order of more than a few percent, efforts should be made to spread the increase over several years. Otherwise, significant non-recoverable *sales losses* are likely to occur. This would require high level coordination among executive agencies, including EPA and the Price Commission (assuming the latter is still in being).

Scheduling to Avoid Disrupting Inter-Model Competition. It is critically important that no financial incentive should exist for any firm to slow down or hold back in its efforts, should a conversion program be undertaken as a result of Federal pressure. To accomplish this, policies should be developed to ensure that consumers are neutral (or favorable) to the technological shift. This *may* conceivably require subsidies or other devices to compensate for engine-related price differentials between models. To accomplish this purpose, uniform introduction of LEA engines for all vehicles sold in specific regions of the country might be advisable.

Scheduling to Avoid Severe Employment Dislocation (especially in engine plants). To accomplish actual production-line conversion in a few years while retaining the existing labor force substantially intact will require very precise coordination of all pre-production activities, including plant construction and machine tool design and production. Disruption of the schedule at any point could have serious consequences both for vehicle manufacturers and their employees, as well as outside suppliers, dealers, etc. Hence, in the event of a federally-induced conversion, every effort should be made to coordinate not only among firms but also among various labor unions affected.

Retraining of Workers with Obsolescent Skills (Especially in the Repair Sector). A rapid changeover of engine production would probably result in a significant number of early-model technical problems requiring adjustment or repair. In addition, it would ensure a turnover of the entire vehicle population over a period of 12 years or so, resulting in rapid build-up of requirements for skills appropriate to the new engine. This problem is most acute in the case of the RFT, since repair and maintenance labor requirements are substantially higher than for the current engine (OC-70). A shortage of skilled repairmen would have very adverse effects on consumers. To ensure the availability of the new skills over such a short period would very possibly involve governmental intervention, if not direct assistance of some sort.

Recycling of Scarce Materials. All low emission engines will require substantially increased consumption of one or more relatively scarce metals. To avoid serious supply bottlenecks, undue dependence on foreign producers, and possible sharp increases in price, a total recycling plan should be developed beginning at the earliest possible moment. Such a plan must particularly address the problem of recovering worn-out parts utilizing scarce materials from dealers, repair shops, and junkyards. Normal market forces cannot be expected to bring about the necessary amount of sorting and recycling, because of lack of functional integration of the raw materials, production, and waste materials sectors, and because of existing policies favoring the use of virgin materials as opposed to secondary materials (e.g., discriminatory freight rates, mineral depletion allowances, etc.). To bring about a high degree of recycling, on the other hand, it may be necessary to design components for easy separation of metals, establish standards of composition, design heavy equipment for efficient sorting and compacting, and possibly require dealers and repair facilities to be licensed, with regular returns of scrap and worn-out parts to a central depot being a condition of retaining their licenses.

The policy implication of a spontaneous (industry-initiated) conversion are rather different simply because such a changeover would probably occur much less rapidly. Price-related problems would be eliminated, essentially by definition. The problems of scheduling and retraining labor in this case would be far less severe. Government intervention might not be needed at all, or, if it were, existing programs might well be adequate. The materials recycling problem, however, would be all the more difficult to solve if the conversion occurred without explicit Federal pressure, due to lack of coordinated planning among the sectors involved.

Acknowledgment

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Mr. BROWN. Mr. Winn?

Mr. WINN. In the interest of time, I may have some questions which I would like to submit in writing to Mr. Ayres. But I would like to ask one thing on the front page of your testimony. I think you make a pretty strong statement here when you say, "However, I do most emphatically believe there is an overriding public interest in this matter and that the automotive industry as presently constituted in the United States has little incentive or will to develop technology alternatives to the internal combustion engine." How would you suggest we in Congress put more pressure on them?

Dr. AYRES. Well, I think the best way is by devising relatively impersonal incentives. The Clean Air Act, for example, did apply certain incentives in one direction. I think Congressman Vanik's proposal with regard to an excise tax that would be related to fuel economy is a very promising kind of an approach. In general, it would be my philosophy to seek incentives that can be implied in an impersonal way without trying to control the decisionmaking process in the industry through direct regulation.

Mr. WINN. Practically all of the witnesses have said that they don't think the Federal Government should become too deeply involved in this?

Dr. AYRES. The Federal Government is deeply involved. There is no getting away from that.

Mr. WINN. As far as controlling?

Mr. AYRES. The question is how should the involvement be structured. I think it should occur by design, not just happen, as it were, by accident. If possible, the optimum way for the Federal Government to influence any industry is by creating an impersonal financial incentive to act in ways compatible with the public interest. I would suggest that the Vanik bill is an example of such a thing. I think there are some questions with respect to that bill, but they are technical in nature.

Mr. BROWN. Would you be willing to respond to written inquiries from the committee in view of the shortness of the time we have here this morning? Do you have any questions?

Mr. SYMINGTON. No.

Mr. BROWN. Thank you very much for your testimony. I think it has made a real contribution to our general understanding of our problem. We will be back in touch with you.

Our final witness today is Dr. John Steinbruner, an associate professor of public policy, John Fitzgerald Kennedy School of Government, Harvard University. Mr. Steinbruner is a coauthor of a recent book entitled, "Clearing the Air: Federal Policy on Automobile Emissions Control."

We welcome you, Dr. Steinbruner, and we apologize for the delay that has prevented you from appearing earlier, and we invite you to proceed with your testimony.

[A biographical sketch of Mr. Steinbruner follows:]

JOHN DAVID STEINBRUNER

Born: July 12, 1941/Denver, Colorado.
Married, two children.

Currently

Associate Professor of Public Policy, John F. Kennedy School of Government, Harvard University.

Assistant Director, Program for Science and International Affairs, Harvard University.

Consultant to the RAND Corporation.

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Education

A.B., Stanford University, Major in psychology, 1963.

Ph. D. in Political Science, Massachusetts Institute of Technology, 1968.

Major publications

John Steinbruner, *The Cybernetic Theory of Decision*. Princeton University Press, 1974.

Henry Jacoby and John Steinbruner, *Clearing the Air: Federal Policy on Automobile Emissions Control*, Ballinger Press, 1973.

STATEMENT OF DR. JOHN D. STEINBRUNER, HARVARD UNIVERSITY, CAMBRIDGE, MASS.

Dr. STEINBRUNER. My name is John Steinbruner. I am associate professor of public policy at Harvard University and assistant director of the program for science and international affairs. I would like to testify on H.R. 10392 based on research I have conducted with Henry Jacoby, professor of management at M.I.T., and a number of students at Harvard. That research focused on the problem of achieving the automobile emissions standards required by the Clean Air Act as amended in 1970. The major results of the research have been published in a book entitled *Clearing the Air* by Ballinger Press of Cambridge in 1973. I have submitted to the subcommittee an article summarizing the main technical argument of the book; namely that the development of an alternative automobile propulsion technology is economically desirable, if the established emission standards are to be achieved.

SALVAGING THE FEDERAL ATTEMPT TO CONTROL AUTO POLLUTION

HENRY D. JACOBY AND JOHN D. STEINBRUNER

In the 1970 amendments to the Clean Air Act the United States has embarked on a major adventure in government regulation. The amendments mandate drastic reductions in the air pollutants emitted by automobiles, and require that they be achieved by the 1975 and 1976 model years. These regulations strike at one of American society's fundamental technologies and impose strict discipline on its largest industry. More than 10 percent of the United States Gross National Product is generated by the production, fueling, and servicing of the internal combustion engine (or ICE) in its automotive application, and the associated social and political forces are commensurately large. The enactment of this legislation over the opposition of the automobile industry was an impressive display of public resolve, and the fact that the industry is now actively working to comply is a major victory for the public interest.

Unfortunately, the regulatory mechanisms set up in the Clean Air Act are too primitive for the complex technical and manufacturing processes to which they have been applied. Unless adjustments are made the results are likely to be unhappy. Under the current policy, consumers and taxpayers will pay an unnecessarily high price for the emission reductions that are actually achieved, and even then the objectives set in the legislation will not be met.

The underlying difficulty has to do with the relationship between the emission standards, the short deadlines, and the state of the art of automotive technology. In essence the emissions standards force conventional internal combustion engine designs against severe natural limits. Controlling the conventional ICE to the levels now required will require sharply increased manufacturing and operating costs and noticeably reduced performance on the road. In order to avoid these severe trade-offs it would be necessary either to introduce an entirely different automotive

technology or to make fundamental changes in the design of the internal combustion engine. Promising alternatives are known to the scientific community, but the manufacturers—who are financially, technically, and even psychologically committed to conventional engines—have focused almost all of their technical efforts on the standard ICE. They have been reinforced in this behavior by the 1975 and 1976 deadlines, since it is unlikely that any of the alternative technologies could be prepared for mass production by that time under constraints on cost and effort generally accepted as legitimate. The result is an abatement program that to date is based almost exclusively on marginal adjustments and bolt-on additions to the conventional ICE.

With the pursuit of pollution control effectively constrained within a relatively narrow and unpromising technical area, four serious problems arise:

1. Approaching the 1975/76 standards with a controlled ICE is likely to be expensive, not only in initial manufacturing cost, but also in terms of fuel and maintenance expenditures.

2. Despite this expense there is a good chance that the conventional ICE cannot meet the 1975/76 standards, even by the late 1970s.

3. Even if the standards are met under the current official definition (which involves emissions tests on prototype vehicles), emission rates on the road are likely to be highly *unstable*. That is, the average emissions of the actual vehicle population can be expected to be significantly higher than the average emission rate calculated on the basis of official test procedures.

4. Control of a highly unstable technology, once it is in the hands of users, would require elaborate federal and state enforcement machinery. Such an effort would involve governmental surveillance and regulation, potentially, of tens of millions of individual polluting units and tens of thousands of firms in the service industry. Such systems would be expensive to set up, and their value in actually contributing to cleaner air is highly questionable.

Moreover, under this policy the natural course of events will run to the relative advantage of the automobile manufacturers. The cost of producing automobiles will increase by a significant amount, but the industry has sufficient financial flexibility to

avoid disruption of the market for new cars. The major costs of emission control promise to arise from increased fuel consumption and maintenance, and these are costs that fall on the consumer after he has purchased the car. Consumer wrath at these costs is as likely to be directed against the government as against industry. Further, in the event that the manufacturers fail to meet the standards, clearly it is the government that will have to yield. The demonstrable benefits to be gained from controlling automobile emissions to the low levels required are not great enough to justify the immense economic, social, and political costs of a halt in automotive production. That enforcement device, the only one available at the moment, is like the hydrogen bomb—too damaging for use against moderate provocations.

Political forces awakened by the Clean Air Act will force a continuing reconsideration of its provisions, and, given the difficulties of the policy established in the act, the government ought to welcome the opportunity to think more deeply into the issue. Three basic options have gained enough support that they effectively define the context of debate. The first of these is to persevere in the established policy in the expectation that the critical technical parameters will eventually yield to a steadfast public will. The second is to relax the emissions standards, thereby accepting levels of pollution higher than those envisaged in the legislation but preserving the conventional automobile engine and realizing substantial cost savings. The third is to adjust the policy to ensure serious preparation of an alternative engine technology. This is likely to involve an adjustment of the established deadlines and the creation of a package of new incentives and regulatory devices.

Despite great uncertainties, the relative merits of these options do admit of serious analysis. In our view the results of that analysis support the third option, and thus suggest the need for a major change in government policy in order to promote rather than retard the development of inherently low-polluting automotive technology.[1]

[1] This analysis is based on a larger study, *Federal Policy on Automotive Emissions Control,* carried out as a joint effort of the Environmental Systems Program and the John F. Kennedy Institute of Politics, Harvard University, and sponsored by the National Science Foundation and the Ford Foundation.

I. History of the Legislation

The 1970 legislation, which established the current policy, was very much the product of the 20-year history of the auto pollution question. The issue itself arose in 1950, when studies at the California Institute of Technology first clearly associated automobile emissions with smog in the Los Angeles basin. It was discovered that photochemical reactions involving hydrocarbons and oxides of nitrogen in the presence of sunlight produce a number of compounds which are irritating and potentially dangerous to sensitive human tissue, particularly lungs and eyes. Shortly thereafter the Los Angeles Air Pollution Control District began encouraging the automobile companies and the state government to take corrective action.

In these early days the manufacturers repeatedly rejected the contention that automotive emissions were a problem. Nevertheless they did set up a study group within the Automobile Manufacturers Association to conduct research and exchange technical information. And in 1954 they reached a cross-licensing agreement among themselves which provided for general use, without royalties, of any air pollution control equipment developed by any of the auto manufacturers.

The first federal legislation came in 1955 with PL84–159, which provided for federally-sponsored research but did not grant the federal government any enforcement powers. It was thus left to California to pass, in 1961, the first law requiring a simple crankcase control device. This was followed in 1963 by legislation requiring exhaust control devices on vehicles marketed in California as soon as two devices were approved by the State Motor Vehicle Control Board. The automobile manufacturers at first denied that they had any such control technology available. But when four devices submitted by independent manufacturers were approved by the California board in 1964, the companies announced that devices of their own manufacture would appear on new cars sold in California beginning with the 1966 model year. The first California emissions standards were then imposed in that year.

The first federal enforcement powers were established by the Clean Air Act in December of 1963, which authorized the federal

government to convene interstate pollution abatement conferences and in some cases to initiate federal suits to force clean-up. It also provided for federal grants to stimulate research and to increase state pollution control activity, and it specifically mentioned the need for further attention to automotive exhaust. A second title to the act was passed in 1965, authorizing HEW to set emissions standards for automobiles beginning with the 1968 model year. A year later HEW announced 1968 standards roughly identical to those that had come into effect in California in 1966. The impression was clearly conveyed that the federal government was assuming enforcement powers slowly and reluctantly, and that federal activity was lagging behind the more aggressive California program.

The political climate which ultimately precipitated the stringent emissions standards began to develop in 1965, when Ralph Nader published his famous indictment of the industry for safety defects and was treated to a personal investigation at the industry's expense. Seldom has an attempt at intimidation backfired so spectacularly. The Nader affair led to a dramatic set of hearings in which the President of General Motors was forced to apologize to Nader in front of a Congressional committee and a national television audience. Serious and lingering damage was done to the political credibility of the automobile manufacturers, and this was soon compounded by allegations concerning their handling of the air pollution problem itself. In January the Los Angeles County Board of Supervisors requested the Attorney General to investigate collusion by the industry to withhold pollution control equipment. The Board of Supervisors charged that the committee of the AMA set up to conduct joint research was in fact a collusive arrangement to prevent the introduction of controls. They cited the package of control devices developed by Chrysler, but kept off the market until California legislation forced its introduction, as evidence that industry developments were being suppressed rather than propagated. The resulting Justice Department investigation ended in a consent decree in 1969 providing for an end to the conspiracy without officially conceding its existence. This incident unquestionably added to the public's impression of recalcitrance and bad faith on the part of the industry.

In 1970, the political forces supporting stronger emission con-

trols finally became overwhelming. The press discovered the pollution issue and began to raise public consciousness. NBC News showed filmclips of diseased trees over 100 miles from Los Angeles. The *New York Times* added a special reporter for environmental affairs, and he and others like him soon announced that environmental protection was the coming issue on American campuses. Earth Day was proclaimed on April 22, and well-publicized nationwide activities called for stronger pollution control measures. Ralph Nader's Center for the Study of Responsive Law published a well-timed report on air pollution attacking both the automobile industry and Senator Edmund Muskie as chairman of the Senate Subcommittee on Air and Water Pollution.[2]

The attack by Nader's study group stung Muskie, then a presidential hopeful. It threatened him in an area where he had established a strong public reputation, and caught him at a time when he was being pressured from several sides. President Nixon had sent a message to Congress in February calling for a 90 percent reduction in emissions standards by 1980 and proposing federally-sponsored research on low-polluting automotive technologies. Whatever the President's actual intentions were, it looked very much like a deft political finesse on a major developing issue. Moreover, Senators Gaylord Nelson and Henry Jackson were issuing proposals for environmental protection which threatened Muskie's jurisdiction over the issue. In August, Nelson introduced a bill bluntly banning the internal combustion engine by 1975. Later that month, in the midst of a pollution incident on the East coast and with a transcontinental Clean Car Race in progress, Muskie took Nixon's standards and Nelson's deadline and fashioned his own program.

The result was the National Emissions Standards Act, enacted in December 1970 as Title II of the Clean Air Act as amended in 1970. It established emissions standards for hydrocarbons (HC) and carbon monoxide (CO) for new cars in 1975, and an additional standard for oxides of nitrogen (NO_x) to be met in 1976. These new standards are to constitute a 90 percent reduc-

[2] The Nader study, *Vanishing Air* (New York: Grossman, 1970), was written by a team headed by John Esposito. It provides a spicy account of events up through the 1960s.

tion below 1970 and 1971 levels respectively. (Administratively, these standards have since been specified as 0.41 gm/mi HC, 3.4 gm/mi CO, and 0.4 gm/mi NO_x.) It also enables the federal Environmental Protection Agency (EPA) to carry out certification tests to confirm compliance, to conduct research, to establish fuel regulations, to require and enforce warranties from auto manufacturers, and to certify and subsidize on-the-road inspection and testing programs. For violations of the emissions standards, the act imposes a fine of $10,000 per vehicle; this is the provision that would, in effect, halt automotive production.

The particular history of this legislation affects the current situation in two critical ways. There remains serious ambiguity concerning the intent of the act, and there is great difficulty in stimulating the development and adoption of advanced automotive technologies. These problems can be traced to the forces that produced the 1970 amendments, and they are important elements of the context in which implementation of the Clean Air Act must proceed.

First, there is the ambiguity regarding the intention to be imputed to the emission standards. From one angle, this legislation can be understood as an effort by Congress and in particular by Senator Muskie and his subcommittee to exert pressure on the obvious political targets by means of legislation. The Congress was moved to do something forceful on behalf of the environment, and the automobile manufacturers, indisputably responsible and politically vulnerable, were an obvious target. The act clearly "got tough" with them, by means of stringent standards, tight deadlines, provisions requiring them to supply data, and language requiring a good-faith effort to comply regardless of the technical difficulties involved. The Executive Branch, controlled by the rival party, was another obvious target, vulnerable because of a sluggish record on enforcement. Congress embarrassed it by removing, through unusually explicit provisions, most of its administrative discretion in enforcing the act. The over-all tone of the legislation is that of forcing a reluctant administrator and a resisting industry to act promptly.

Ironically, this is precisely the interpretation now favored by the automobile industry. Since the manufacturers are in no position to refuse to comply with the legislation, what they now want

is to minimize the disruption to their normal business which compliance will entail. They have substantial and well-advertised efforts under way to develop control devices, and they clearly hope that these efforts, rather than actual achievement of standards, will be construed and accepted as compliance. In order to define compliance in this way, the standards must be interpreted as a first approximation by Congress, whose intent was not necessarily an actual 90 percent reduction but only achievement of the lowest emissions levels that are technically "reasonable." The preponderant technical opinion is that the technically reasonable rates would be less stringent than those associated with the 90 percent reduction objective.[3]

The opposing interpretation of the act holds that the exact value of the 90 percent objective is of real social significance. The figure can be associated with calculations of the amount of reduction necessary to ensure that ambient air conditions in all American cities would remain below levels associated with adverse health effects. These calculations are presented in the legislative history.[4] If the calculations are correct, then a failure to meet the standards would damage the health of a significant element of the general population, and a relaxation of the standards would be much harder to justify.

This question of interpretation is destined to be hotly contested as implementation of the policy proceeds. Not only is the legislative history ambiguous, and the emissions reduction genuinely difficult technically, but the validity of the calculations used to justify the 90 percent objective also are open to question. The atmospheric processes that link emissions to levels of pollution in the air are as yet poorly understood. The effects of automotive pollutants at ambient concentrations are extremely subtle and

[3] For example, see National Academy of Sciences, *Semiannual Report by the Committee on Motor Vehicle Emissions to the EPA* (Washington, D.C., January 1, 1972).

[4] The specific figure of 90 percent was given in an analysis by D. S. Barth and others of the National Air Pollution Control Administration (now part of EPA). Their analysis showed that a 90 percent reduction was required to reduce ambient concentrations of CO, HC, and NO_x below those associated with adverse health effects. See D. S. Barth, *et al.*, "Federal Motor Vehicle Emission Goals for CO, HC, and NO_x Based on Desired Air Quality Levels," in *Air Pollution—1970* (Hearings Before the Subcommittee on Air and Water Pollution of the Committee on Public Works, U.S. Senate, 91st Congress, 2nd Session; Washington, D.C.: Government Printing Office, 1970), Part V.

inherently difficult to measure. Thus the data on which damage estimates must be based are not very robust, and conclusions cannot be established beyond valid scientific doubt.[5] The resolution of this question—either affirmation of the 90 percent objective or an adjustment for technical convenience—will be one of the central issues of the developing program.

The second critical theme which emerges from the history of the emission control program involves the development of automotive technology. In 1969 the Office of Science and Technology formed an Ad Hoc Panel on Unconventional Vehicle Propulsion to assess the possibilities of achieving low emissions with the ICE and to compare this with other technologies. The panel reported officially in March of 1970, advancing the judgment that modifications of conventional engines were not a promising route to low emissions and recommending a federal program to develop an alternative technology for the purpose of emissions control.[6] The recommendations of the OST panel were incorporated in President Nixon's message to Congress on environmental quality delivered in February of 1970, where he announced a new program of both governmental and private-sector research on advanced low-polluting automotive technologies. The result was the Advanced Automotive Power Systems (AAPS) program which was placed in the newly organized Environmental Protection Agency. The program included funds for research directly commissioned by the government and funds for buying prototype vehicles developed by private parties.

In accord with the President's preferred time schedule, officials of the AAPS program laid out a plan to develop steam and gas turbine engines for production in 1980. In terms of this plan the vehicles would be in early prototype stage by 1975, leaving five years to solve the numerous problems involved in reorienting production, marketing arrangements, service facilities, and so on. This plan, caught up in the larger politics of the issue, never really got started. The 1975 deadline for production vehicles, which Muskie's bill imposed, disrupted the time schedule and

[5] An analysis of this aspect is provided by W. Ahern, "Measuring the Health Effects of Reductions in Automotive Air Pollution," Appendix 3 to *Federal Policy on Automotive Emissions Control, op. cit.*

[6] Office of Science and Technology, "Report of the Ad Hoc Panel on Unconventional Vehicle Propulsion" (internal document; Washington, D.C., March 1970).

caused the program managers to change their orientation. Rather than focusing on technical development as such, it was decided that the program should be used as another device to force compliance with the 1975 and 1976 standards. With this change the program lost coherence and purpose since, within the technical constraints imposed, the manufacturers undertook much larger efforts on their own.

Furthermore, the AAPS program was not funded at a serious level. Though authorized at a total of $55 million for a three-year period, actual appropriations have not exceeded $11 million in any year. Probably because it represents the President's initiative (and certainly because they do not trust the technical competence of the EPA), Congress has not shown any enthusiasm or generosity toward the program. Neither has the Office of Management and Budget, which has cut program budget requests, arguing that it is the industry's business to conduct automotive research. The President, outflanked politically, has not bothered to push his initiative. The result is a nominal effort which can be cited as evidence of federal concern whenever there is pro-environmentalist political pressure, but which offers no serious possibility of accomplishing the development of a marketable alternative technology.

The conclusion of the OST panel remains, however: If the nation wishes to reduce automotive emissions by anything like 90 percent, then it had best change its automotive technology or at least contemplate such a change. As the analysis below will show, that conclusion ought to be taken seriously.[7]

II. The Current Technical Situation

In order to analyze the various policy options now available, it is necessary to delve, albeit briefly, into some technical aspects of automotive emissions control. There are fundamental difficulties in holding one hundred million ICE-powered vehicles to close emissions tolerances, and it is important to understand what

[7] The latest report by the National Academy of Sciences, released just as this analysis goes to press, supports this conclusion. See the *Report of the Committee on Motor Vehicle Emissions* (Washington, D.C., February 12, 1973).

the problems are and what other propulsion technologies may offer a way out of the current dilemma.[8]

Difficulties of Emissions Control

In essence, the operation of a conventional spark-ignited internal combustion engine involves a series of contained explosions. Because of the physical and chemical characteristics of combustion under these conditions, there are trade-offs among engine performance parameters such as (1) fuel economy, (2) emissions of CO and HC, (3) emissions of NO_x, (4) engine performance (i.e., pickup and top speed), (5) vehicle driveability (including the propensity to hesitate, stall, or surge, and the relative ease of starting the engine), and (6) cost of manufacture. A desirable change in one dimension—say a reduction of the NO_x emission rate—will produce unfavorable changes in other parameters, other things being equal. Thus the strong, simultaneous controls on HC, CO, and NO_x emissions which the Clean Air Act mandates will involve inevitable and potentially severe costs in manufacturing, lost fuel economy, and reduced vehicle performance and driveability.[9]

These technical trade-offs strongly affect the emission control package now programmed by most manufacturers for their 1975 and 1976 models. In 1975, the controlled vehicles will include a system for leading some of the engine exhaust back into the carburetor (normally referred to as exhaust gas recirculation or EGR). They also will have an air pump and thermal reactor, and an oxidizing catalyst. In 1976, it is likely that a reducing catalyst will be added and the degree of EGR somewhat reduced. These devices must be tightly integrated with a number of engine modifications, such as changes in timing and air-fuel mixtures,

[8] An excellent review of the ICE emission control problem and of alternative technologies is available in a report by the National Air Pollution Control Administration, U.S. Dept. of Health, Education and Welfare, *Control Techniques for Carbon Monoxide, Nitrogen Oxide, and Hydrocarbon Emissions from Mobile Sources* (NAPCA Publication No. AP-66; Washington, D.C.: Government Printing Office, March 1970).

[9] Indeed, a deterioration in vehicle quality is already evident from the controls imposed on the 1971–1973 models, as can be seen in current advertising (particularly for gasoline) that plays to the motorist's displeasure with lost performance and driveability.

which are required in order to produce the proper combustion characteristics. The operating parameters of the controlled engine must be held within narrower limits than is the case with un-somewhat lower than the standards. Unfortunately, provisions controlled engines, and this requires more precise production tolerances. All these changes contribute to increased manufacturing cost.

With this particular control package, the performance of the vehicle is affected in a number of ways: EGR reduces peak combustion temperatures to control NO_x formation, but it tends to interfere with normal combustion and to cause roughness, stalling, and stumbling of the engine. Additional fuel is added to the combustion mixture to counteract some of the undesirable effects of EGR, but this causes greater formation of HC and CO and increases fuel consumption. Thermal reactors and catalytic convertors are added to remove residual HC, CO, and NO_x from the exhaust stream. These cause back pressures on the engine and reduce its effective power. As a result, the optimal settings of engine parameters for purposes of emission control are different from those that give the best fuel economy and engine performance. The controlled engine is more sensitive and complicated than earlier internal combustion designs; it will be more prone to deterioration of performance and will need more maintenance. Due to the complexity of the systems, the maintenance will be harder to perform.

The "Stability" Problem

These technical trade-offs, combined with the requirement for tighter production tolerances and increased maintenance, make it likely that the controlled ICE will not be in stable equilibrium at the level of the 1975/76 standards, even if new test vehicles do pass the federal certification procedure. Emissions performance will tend to deteriorate over time and with distance travelled.

Now it is true that the test procedures for certifying compliance with the 1975/76 standards include a mechanism for limiting the degree of deterioration of controlled vehicles.[10] Prototype vehicles

[10] A study of federal test procedures has been prepared by M. Weinstein and I. Clark, "Emissions Measurement and the Testing of New Vehicles," Appendix 1 to *Federal Policy on Automotive Emissions Control, op. cit.*

must be run for 50,000 miles with no greater than normal maintenance and still perform within the standards. In effect, this means that automobile manufacturers must counteract whatever intrinsic deterioration there is by achieving initial emissions rates of the federal certification test are not proof against the inherent dirtiness of conventional internal combustion engines. There are several reasons why vehicles will be *unstable* in the sense that on-the-road emissions rates will rise above those experienced in the prototype test

1. The *de facto* rate of deterioration will be higher than that accounted for under the federal procedures because on-the-road driving conditions are more demanding and more damaging than those simulated in the prototype durability test. Currently, the 50,000 miles are accumulated by the manufacturers' own expert drivers during the summer months at 35 mph on carefully maintained test tracks. In addition, the maintenance that vehicles receive in real life is not nearly so thorough nor so competent as that given the prototype test vehicles by the manufacturers' expert mechanics.

2. In the absence of elaborate government enforcement, few motorists will perform any specific air quality maintenance at all. Most vehicles will receive the maintenance necessary to make them run well, as they do now, and this will tend to *increase* emissions rather than reduce them.

3. Because emission controls reduce engine efficiency and performance, there is a significant incentive for individual owners to disable, disconnect, or remove the devices. Many motorists will do this kind of tampering, and greatly increased emissions will result.

The single most significant element of the stability problem is the performance of oxidizing and reducing catalysts. If the 1975 HC and CO standards are to be achieved, the oxidizing catalysts must remove 80 percent or more of the pollutants in the exhaust stream. In order to meet current federal durability requirements, this efficiency rate must be maintained for 50,000 miles. Unfortunately, none of the oxidizing catalysts tested to date has been able to achieve 50,000-mile durability, and those in the accepted range of efficiency do not even approximate the required performance. The prospect, then, is that the oxidizing

catalysts will have to be replaced periodically, thus adding further burdens to the maintenance program. For the reducing catalyst which may be used to control NO_x emissions, these problems are far worse.

In addition to these problems of normal operation, there are many conditions that cause the catalysts to fail completely. They can be deactivated by lead, phosphorous, or sulphur. Though lead is unlikely to be a problem at the manufacturer's test facility, it presents serious difficulties for the transition period on the road, when leaded gasoline will presumably have to be supplied for older vehicles. Phosphorous and sulphur also can do damage, even in small amounts, and thus they pose a problem of regulating the composition of fuel and lubricants. Many oxidizing catalysts also can be destroyed by excess heat generated by their own operation. The reactions which oxidize HC and CO generate heat. Thus engine misfirings, rapid acceleration, heavy loads on the engine, or any other driving mode which puts a large amount of unburned fuel into the exhaust will heat the catalyst to temperatures at which many catalysts will be deactivated. Once again, these events are unlikely to occur under prototype test conditions, but they are inevitable on the road. Some manufacturers are planning by-pass valves to protect the catalyst; others will simply allow the deactivation process to occur.

Since ICE-powered vehicles are likely to be unstable, consideration must be given to measures to enforce emissions limits on vehicles on the road. This might be done by a massive inspection system which would try to identify high-polluting vehicles and send them back for mandatory emissions-control service or parts replacement. If tried on anything approaching a nationwide scale, the task would be a staggering one, involving the individual inspection and regulation of tens of millions of individual units. At present few states have the capacity to run such programs, and political opposition, inertia, inefficiency, and budget constraints will hinder their development. Inevitably, a substantial portion of vehicles will escape effective enforcement.

In short, projections of the effect of various emissions control policies must include some estimate of the instability factor. Forecasts based on the legislated maximum emissions rate are hopelessly optimistic. Likewise, it is not reasonable to assume

that the stability problem will be easily cured by systems of in-use inspection and maintenance. The real difficulties of implementing such large-scale programs, and the low likelihood of their even being tried in most states, need to be taken into account.

Costs of Controlling the ICE

There have been several studies of the cost of attempts to meet the emissions standards with the conventional ICE. Table 1 summarizes the estimates of expected increases in manufacturing cost and fuel consumption. Looking first at new car cost, the estimated increase to meet 1975 standards for CO and HC (over the cost of 1973 vehicles) is between $164 and $214 per car. The net increase over costs of uncontrolled vehicles (shown in parentheses) is about $100 more, reflecting the controls imposed between 1967

Table 1. ESTIMATES OF THE INCREASE IN FIRST COST AND FUEL CONSUMPTION, OVER 1973 VEHICLES, TO MEET 1975 AND 1976 EMISSIONS STANDARDS. (NUMBERS IN PARENTHESES ARE ESTIMATES OF INCREASES OVER UNCONTROLLED VEHICLES.)

	Additional Manufacturing Cost Per Car		*Increase in Fuel Consumption* (percent)	
Source	*1975 Controls*	*1976 Controls*	*1975 Controls*	*1976 Controls*
National Academy of Sciences [a]	$214 ($314)		3%–12%	
Chase Econometric Associates [b]	$164 ($247)	$269 ($352)		
Esso Research and Engineering [c]				5%–20%
Chrysler Corp. [c]				(30%)
General Industry Estimates [d]		($245–500)		(10%–26%)

[a] *Semiannual Report by the Committee on Motor Vehicle Emissions to the EPA*, January 1, 1972.
[b] "Phase II of the Economic Impacts of Meeting Exhaust Emission Standards, 1971–1980," December 1, 1971.
[c] Testimony to the EPA Auto Emissions Standards Hearing, May 1971.
[d] Private interviews.

and 1973.[11] The cost to meet the 1976 standards (including the stringent controls on NO_x) is between $270 and $400 per car, as compared to 1973 vehicles. For an annual model run of 10 million cars, the total increase in manufacturing cost entailed by the 1976 standards would range between $1 and $4 billion per year.

The increase in fuel consumption caused by 1975 and 1976 emissions controls has been variously estimated, as indicated in the two right-hand columns of Table 1. Our analysis uses a range of values from 5 to 20 percent above the gas consumption of 1973 vehicles; it indicates that, unless technical improvements are achieved, fuel costs will be increased by $1 to $4 billion per year by the mid-1980s.[12]

One of the primary effects of emissions control procedures applied to the ICE is that the engine becomes more complex and more sensitive. It will require more maintenance just to keep it performing adequately, let alone to hold its emissions close to the official standards. Only the roughest guess can be made as to the actual economic costs of increased maintenance, but it seems reasonable to forecast a direct maintenance charge on the emission control program of $10 to $20 per car per year—in essence this is 1/4 to 1/2 the cost of one additional visit to the garage each year.

If an attempt is made to handle the technical instability of the controlled ICE through a program of vehicle inspection and enforced service of air quality devices, this will add at least $3 per car tested. The mandatory servicing of control devices on the cars that fail the test will cost in the neighborhood of $20 to $30 per vehicle. If the inspection is annual and roughly a third of the cars fail, then the enforcement program itself could cost over $1 billion per year.

When all these items are added together the total cost of the abatement program is impressive. In the 1980s it will cost from $4 to $10 billion per year to control emissions from the conventional ICE.

[11] The costs of controls imposed up through the 1973 model year are sunk costs and are not included in the analysis of future policy changes.

[12] There has been a fuel penalty of 5 to 10 percent as a result of controls up through 1973, but again this is a sunk cost and is not included in the analysis. We assume a gasoline price (net of taxes) of $.25 per gallon and a base fuel economy of 15 mi/gal.

Alternative Propulsion Technologies

The high cost and inherent instability of the tightly-controlled ICE leads one to look for alternative means of propulsion that are less polluting. A number of alternatives exist, the most prominent of which are the Wankel, the stratified charge ICE, steam and gas turbine engines, electric drive, and engines that run on various types of clean-burning fuels. All of these, along with various hybrids, are sufficiently different from the conventional ICE to require substantial redesign of vehicle components and production processes. Short of a major national commitment (much greater than anything suggested to date), such an effort cannot be accomplished by 1976 or 1977. If intensified developmental efforts were to begin in 1973, however, any of these alternatives could be prepared by 1980, with varying degrees of confidence in a satisfactory outcome.

The Wankel Engine. The Wankel engine is attractive t[illegible] automobile producers quite apart from its emissions characteristics. For the power delivered it is smaller, lighter in weight, and has fewer moving parts than the standard ICE. Since the structural weight of a vehicle is related to the weight of the engine, a lighter engine translates into savings in manufacturing cost. Moreover, Wankel engines can be constructed in modules, offering the promise that engines of different size can have the same basic design, and vary only in the number of rotors. The performance of the engine compares favorably to standard ICEs of contemporary design. The major problem concerns fuel consumption, which is high at the moment and appears to be difficult to improve.

Unfortunately, the Wankel is not especially advantageous from the standpoint of emissions control. Because of the elongated combustion chamber of the Wankel engine, there will be more quenching[13] of combustion than in a standard ICE and hence greater concentration of unburned HC in the exhaust. Formation of NO_x is slightly lower in the Wankel for the same reason, and

[13] "Quenching" refers to the phenomenon whereby combustion is retarded along the walls of the cylinder because they are cooler than the body of burning gas. Thus quenching stops combustion short of completion and leaves unburned hydrocarbons in the exhaust.

because there is a certain amount of exhaust gas recycling inherent in the operation of the engine. Since additional EGR cannot be added, however, without disrupting engine performance unacceptably, reducing NO_x to the 1976 standards is a problem. The Wankel will have to be carefully tuned to minimize emissions formation and, as with the standard piston engine, these adjustments may cause significant losses in fuel economy and road performance. Thus the Wankel engine will have many of the same stability problems as plague the ICE, and will be even more dependent on the performance of catalysts and/or thermal reactors in the exhaust stream. If control devices fail, the resulting HC emissions from a Wankel will be greater than from a standard ICE.

Stratified Charge ICE. The Ford Motor Company, under contract to the Army Tank Command, is working on an engine that cleans up the internal combustion process by concentrating fuel around an internal ignition point and maintaining much leaner mixtures in the outer portions of the cylinder. The design of the cylinders and engine block is a significant departure from that of the conventional ICE. Combined with catalysts, a prototype engine of this sort has achieved the 1975/76 emissions standards over short durations. The principle is also being applied to Wankel engines.

There are several problems with the Ford stratified charge engine that require further research and development. It requires very precise control of mixing in the combustion chamber, and this makes it more complex than the conventional ICE or the conventional Wankel. Both production and operating tolerances have to be tighter than with current vehicles. It would therefore be more costly to produce (potentially \$250–\$350 per car more than the controlled ICE). It also might be less stable in actual operation. Emissions would increase significantly as it wandered out of tune, and tuning for best emissions control may be different from tuning for best economy.

More encouraging results have been achieved by a Japanese manufacturer, Honda. The Honda design is different from that of the Ford engine, in that it involves a small pre-combustion chamber for each cylinder, and it appears to be both more durable and less costly. As yet the Honda approach has been tested only

on small engines, and the difficulties of adaption to the standard American car are not yet fully known. Clearly, however, the stratified charge engine is very promising, and it merits more attention than it is now receiving.

Rankine Cycle. Rankine cycle engines use continuous combustion to heat a working fluid (water or some organic solution) which then expands against pistons (or a turbine) to produce the work required to propel a vehicle, as with the old Stanley steamer. Such an engine has several attractive features. Relative to the ICE, it produces high torque at low engine speeds and thus does not require a complicated transmission. It can run on low octane gasoline as well as on less refined fuels, such as kerosene. Because the fuel is not exploded it is a quieter engine. It also is extremely durable and would require less maintenance and, presumably, less frequent replacement than an ICE. There are no barriers to mass production, and such engines could be prepared for the automotive market at a cost roughly equal to the tightly controlled ICE ($1200–$1300 per unit or about 30 percent more than the cost of current engines). Fuel economy (10–15 miles per gallon) promises to be comparable to the current ICE.

Rankine engines offer stable low emissions. Combustion is more complete and thus the engine exhausts far less HC and CO than an ICE. Also, the gases cool less rapidly after combustion, and so there is less formation of NO_x. Even without special efforts to control emissions, experimental Rankine engines have produced emissions of less than 0.2 gm/mi for all three pollutants—less than half of the 1975/76 standards for HC and NO_x and a tenth of the 1975/76 standard for CO.

The traditional disadvantages of the Rankine engine—freezing of the working fluid in cold weather, slow start-up, danger of boiler explosion, use of scarce materials, and sheer bulk—have all been either eliminated or greatly reduced even with the small amount of research done in recent years. Organic working fluids now being tested freeze only at −30°F. There is no boiler as such to explode, and if a leak should develop in the tube where the working fluid is heated, not enough would escape to constitute a hazard. Start-up times are now down to 30–40 seconds, and it is doubtful that this would prove much of an inconvenience, particularly since starting would be more reliable than for a

controlled ICE. At the moment Rankine engines are heavier than the ICE, but this disadvantage is reduced if account is taken of the transmission, which is heavier for an ICE-powered vehicle. Recent advances in condensers, heat exchangers, and expanders have reduced the volume of the engine, which will now fit into the smaller model lines currently on the market (e.g., a Ford Fairlane or a Chevy II).

The major disadvantage of the Rankine, as with any radically different alternative, is that such engines are not now in use, and therefore the technical momentum of the industry works against them. Even if Rankine technology were universally acknowledged as superior (which it is not), there would be difficulties in overcoming the well-established commitment of the industry to the ICE. Though their durability and emissions characteristics may make Rankine cycle engines attractive from the point of view of the motoring public, the manufacturers, faced with costs of reorganization and retooling, are inevitably less enthusiastic.

Gas Turbine. The gas turbine engine is an automotive adaptation of the technology commonly used in jet aircraft. It has very attractive thermodynamic properties, and yields power and energy densities (the determinants of speed and range) greater than those of the ICE. Because of its thermodynamic characteristics, and because the aircraft industry has given it an independent (and conceivably competitive) base, the gas turbine has long received a significant amount of attention from the automobile manufacturers. Apart from the ICE, it is the alternative with which the industry is most familiar and the one (at least until the advent of the Wankel) to which it is most favorably inclined.

In terms of emission control the gas turbine is inherently cleaner than the ICE and much more stable. A properly tuned turbine engine produces HC and CO emissions in the area of the 1975 standards and these rates do not seriously degrade over the life of the engine. There is a problem with NO_x, however. Although NO_x formation is lower than in the uncontrolled ICE (around 2 gm/mi), it still is significantly higher than the 1976 NO_x standard, and there is no control technique at the moment which will reduce it. Of course, even with higher initial emission rates, the gas turbine might well produce less pollution than the controlled ICE because of its greater stability.

There are barriers to the mass production and mass operation of gas turbines in automobiles. They require exotic materials and more tightly controlled production processes than the automobile companies have attained to date. The manufacture of turbine engines might require drastic changes in the current labor force, either in terms of training or of personnel turnover. There would be similar problems in the maintenance industry: The turbine could not be handled by current garage mechanics. The unit price of the engine is hard to predict, but it appears that it would be significantly higher than the controlled ICE ($1500 or so by current estimates).

Electric Drive. Recent research has identified new battery technologies that have sufficient power output and energy storage to permit an automotive application. If fully developed, such batteries might power a passenger car with the speed, range, and performance of current ICE's at a competitive cost. Such a vehicle would have no HC, CO, or NO_x emissions whatsoever, and would be quieter, smoother, and more durable in operation. The pollution problem under such a technology would be displaced to a smaller number of larger sources (i.e., electric power generating stations), where over the long run it is not unreasonable to hope for significant economies of scale in pollution reduction and significant advantages in enforcement.

Such vehicles also would enable a more flexible energy policy, and could help to conserve petroleum. At some point in the future, fossil fuels will become too scarce and expensive to use for propelling individuals around in 4000-pound containers. Naturally, there is great debate about how far in the future this event lies and whether it is desirable to effect such a change at an earlier date in order to reap benefits in terms of reduced pollution.

It would require a substantial (but by no means unattainable) development effort to prepare electric drive technology for mass production by the early 1980s. Though such an effort is very unlikely to emerge from current market forces, it would be attainable with government financing. The more serious barriers to electric drive technology are to be found in its broader economic consequences. The reallocation of the productive capacity

of the automotive manufacturers would be much more substantial than in the case of the Rankine cycle, Wankel, or stratified charge engines. Disruptive effects would be concentrated in markets for certain materials and parts. Oil producers and distributors would lose their gasoline market, which currently is the major portion of their business, though this would occur at a gradual pace determined by the turnover in the vehicle population. Electric utilities would experience a greater increase in demand than they are now estimating, and they would have to undertake greater capital investment. This again would be a gradual process phased to the vehicle turnover rate.

The essential question then is whether long-run economic forces favoring electric technology will appear *soon enough*, or whether the gains from centralizing emissions sources will be significant enough, to make a battery-powered car competitive within the time frame of current policy (15–20 years). This is a matter of great uncertainty. But since the decisions on automotive technology now being forced by the Clean Air Act will strongly affect the patterns of energy use at least until 1990, the issue ought to receive serious and immediate attention.

Internal Combustion Engines with Gaseous Fuels. It has been demonstrated that dramatic reductions in exhaust emissions from the conventional ICE can be achieved by changing to gaseous fuels such as liquified petroleum gas or compressed natural gas. Such systems, which require only moderate changes in engine design, have inherently clean combustion and good performance characteristics, and they result in stable emissions near the levels of the 1975/76 standards. Some taxi fleets and pools of government vehicles have been converted to gaseous fuels in recent years, often with net savings in vehicle cost.

The main problems with gaseous fuels concern the supply system and safety.[14] A major increase in the national supply of gaseous fuels would be required (perhaps through coal gasification or imports of liquified petroleum gas) in order to serve the national vehicle fleet. Even if the supply were available, the widespread use of gaseous fuels would require a major overhaul

[14] A very useful analysis of gaseous fueled vehicles has been carried out by the Environmental Quality Laboratory at California Institute of Technology; see L. Lees, *et al.*, *Smog—A Report to the People* (Los Angeles, 1972).

of the distribution system for automotive fuels. These two factors tend to restrain the use of gaseous fuels to fleet operations in large cities. The safety problem appears to be as much a matter of public acceptance as of real danger. Most analyses of the safety question conclude that a properly-run gaseous fuels system is as safe as one based on gasoline, if not more so.

A more venturesome approach now under study would involve the use of hydrogen as an automotive fuel. The hydrogen could be made from hydrocarbon fuels or from water (using electric power as an input) and delivered in liquid form much as gasoline is today. Or it might be manufactured from a conventional hydrocarbon fuel within the vehicle itself. A hydrogen engine would be essentially pollution-free. As with other alternatives mentioned above, additional research is needed to determine if these new approaches are practical for mass-produced cars.

One thing is clear, however. Technologies are available that can be expected to solve the stability problem and that could be developed for new car production by, say, the model year 1981. It is unrealistic, however, to think that any of these potential solutions will emerge in a timely fashion from the current emission control program.

III. Policy Options

A fertile imagination can generate a large number of different approaches to the automobile emissions control problem. These include an outright ban on the ICE, myriad systems of effluent taxes, enforced maintenance, gasoline rationing, traffic controls, regional rather than national programs, and a substantial reduction in the abatement objectives. A full evaluation of the options would require a very extensive discussion indeed. As a practical matter, though, there seem to be three basic options, illustrated in the top half of Figure 1. One option is to continue with the established policy of full implementation of the Clean Air Act as it now stands. In this case there is a subsidiary choice about how hard to push for enforcement of emissions performance "on the road." We shall refer to this option by the shorthand notation "EST," or if an enforcement program is included, as "EST/ENF."

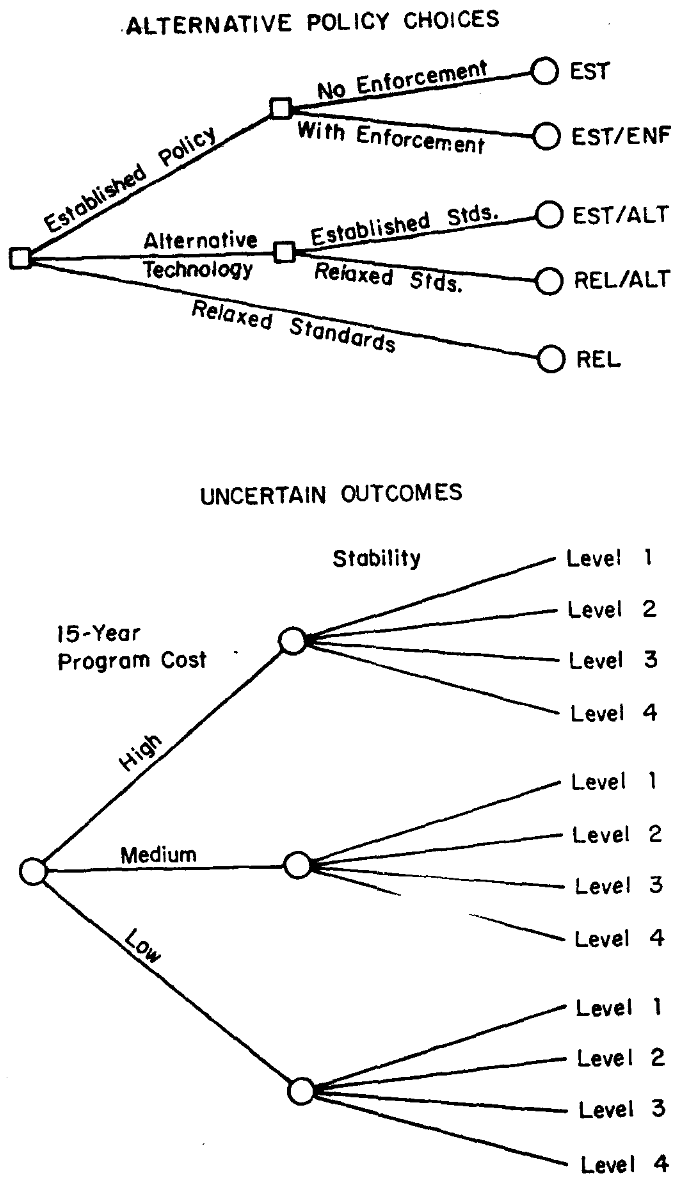

Figure 1. SCHEMATIC VIEW OF ALTERNATIVE POLICY CHOICES, AND OF UNCERTAIN OUTCOMES UNDER EACH OF THE POLICIES.

A second option is to relax the current emissions standards to technically convenient levels in order to avoid all the difficulties discussed above. This we shall refer to as option "REL." And

the third option, which we call "ALT," is to adopt a vigorous program to develop one or more of the low-polluting propulsion technologies, and to prepare for its adoption in the early 1980s. In this last case there is a subsidiary choice about what to do about emissions standards while this alternative is being prepared. On the one hand, it is possible to hold to established standards through the late 1970s (leading to option EST/ALT), or standards can be relaxed in the interim, to be raised again in the early 1980s (yielding option REL/ALT).

No matter which path federal policy takes, there is a wide range of possible outcomes, as displayed in the bottom half of the figure. First, there is the question of program cost over some period (we use 15 years), and our analysis will utilize high, medium, and low assumptions about the costs of emissions control. Then, whatever the cost turns out to be, after some years of experience with vehicle deterioration under road conditions there will be some realized level of emissions stability. As the figure shows, the analysis will incorporate a range of assumptions about the degree to which vehicle emissions deviate from those predicted by the prototype test. The relative attractiveness of different policy options, naturally, depends on where they are expected to come out on the diagram of cost and stability.

Established Policy

When understood in the context of the 1960s the provisions of the Clean Air Act have a simple, appealing logic. The act gets tough with the oligopoly of domestic manufacturers who are widely believed to have colluded to fend off California's early attempts at emissions control. The rigidly imposed standards and precise deadlines, the clause requiring good-faith effort to meet them, and the threat of prohibition from the market are all devices for breaking the resistance of recalcitrant profit-oriented industrialists. Explicit constraints on auto emissions are given the force of law. Enforcement of explicit standards requires measurements which must be recorded and made part of the public record, and this provides a political focus and a pressure point for diffuse and weakly-organized environmentalist forces. Moreover, the difficult task of designing control systems is left to the manufacturers, who

have an incentive to produce the most efficient technical solution, so the argument goes. State inspection programs, along with the warranty provisions of the act, should prevent manufacturers from producing a vehicle that turns into a bad polluter after a few months in the owner's hands. The implementation of this logic can accurately be referred to as the "established policy" of the Congress and the EPA.[15]

There is some chance that this approach may produce an efficient method of controlling ICE emissions. Perhaps there are breakthroughs in technology and production technique that can yield dramatic reductions in emissions at low cost, with no undesirable side-effects. (Catalyst manufacturers are in effect making such a claim when they forecast the development of cheap, durable, highly efficient catalytic devices.) Such an outcome would be an extraordinary bit of good luck, and it would clearly justify the established policy. The technical momentum of the industry and the political forces behind the current policy would be directed down the right track, and at least one environmental problem would be solved.

Unfortunately, if the technical breakthroughs are not so easily achieved, then the virtues of the established policy are much more problematic. Despite official neutrality with respect to propulsion technology, the 1975/76 standards and deadlines serve to lock the entire industry into a narrow range of options. Routine production procedures in the industry require that basic engineering designs be established three years before production begins (July 1972 for the 1975 models). This timing allowed only 18 months between the enactment of the 1970 Amendments (whose stringency was not anticipated by the industry) and the onset of the production cycle for 1975 vehicles. The tight deadline could not help solidifying the commitment throughout the industry to the conventional ICE and to "bolt-on" clean-up devices.

If the technical trade-offs hold in this circumstance, then the response of automotive designers, working under time pressure, is predictable. They will aim for a vehicle design that (a) will pass the federal prototype test so it can be sold and (b) will

[15] There are important matters which have not been decided to date, including elements of certification testing and assembly line surveillance, guidelines for vehicle maintenance and state enforcement, and the question of an extension of the 1975 and 1976 standards.

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entail the least possible increase in new car cost and the smallest losses in vehicle driveability. To do so, they will have to compromise with vehicle emissions performance over long periods of time and miles of use. Vehicle emissions will tend to be "unstable" in the sense that, without continuous and informed maintenance, emissions rates will rise significantly under the rigors encountered on the road.

Emissions Forecasts. Just how high emissions might go is a matter of considerable uncertainty. The factors contributing to instability have been identified above. The degree to which they operate will depend both on vehicle design and the pressure of government enforcement. In order to analyze these phenomena we have developed a set of models of the automobile population, taking into account the growth, turnover, and use patterns of vehicle fleet, along with the differing emissions standards in force in different years. They also contain sub-models of vehicle deterioration under road conditions, and of auto emission inspection and enforced maintenance.[16]

The key to the analysis, as noted earlier, is the concept of "stability" of vehicle emissions over time. A vehicle type is "stable" if it will, on the average, perform near to the prototype test result even without elaborate enforcement systems and specialized emissions control maintenance. The greater the increase in emissions under these conditions, the more "unstable" a particular design is considered to be. We define four stability levels that cover the range of emissions performance that could result from current efforts to control the ICE. There also is a stability class designed to represent a stable alternative technology. Figure 2 shows a simplified version of this part of the emissions model. Each level of stability indicates a different possible state of the world which might result from the inherent properties of the vehicle design, voluntary maintenance, the driving habits of the population, and the other factors affecting emissions control system deterioration.

Level 1 stability reflects what might be achieved if vehicle design and production were at the most favorable limits of imaginable success and if vehicles were voluntarily maintained

[16] See "Enforcement of Emissions Limits 'On the Road'," Appendix 2 to *Federal Policy on Automotive Air Pollution, op. cit.*

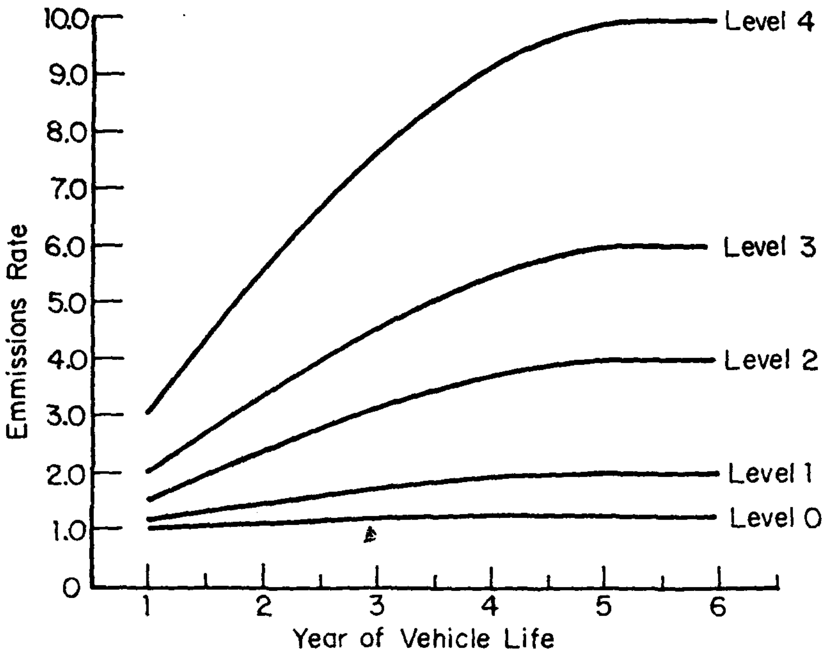

Figure 2. EMISSIONS RATES FOR DIFFERENT STABILITY LEVELS ON THE ASSUMPTION THAT NO SPECIFIC EMISSIONS CONTROL MAINTENANCE IS PERFORMED, STATED AS A MULTIPLE OF THE PROTOTYPE TEST RESULT.

exactly according to manufacturer's specifications. It presumes a catalyst that would not fail completely even under high temperature, rough driving, or poisoning. This level of stability is very unlikely to occur, but it is conceivable and thus serves to define the lower end of the range. Level 4 stability is the high end of the range. It presumes a catalyst which is prone to failure, and a significant amount of perverse maintenance (adjusting or removing of control devices in order to improve performance at the cost of higher emissions). Further, it assumes that whatever air quality maintenance is done will be inexpertly performed. Levels 2 and 3 represent intermediate cases to provide reference points within the established range. Level 0 stability indicates the performance that could be expected from a stable alternative technology.

Using the emissions model and these definitions of stability, we can prepare alternative emissions forecasts. Taking CO as an example, Figure 3 shows the annual total emissions for the nation

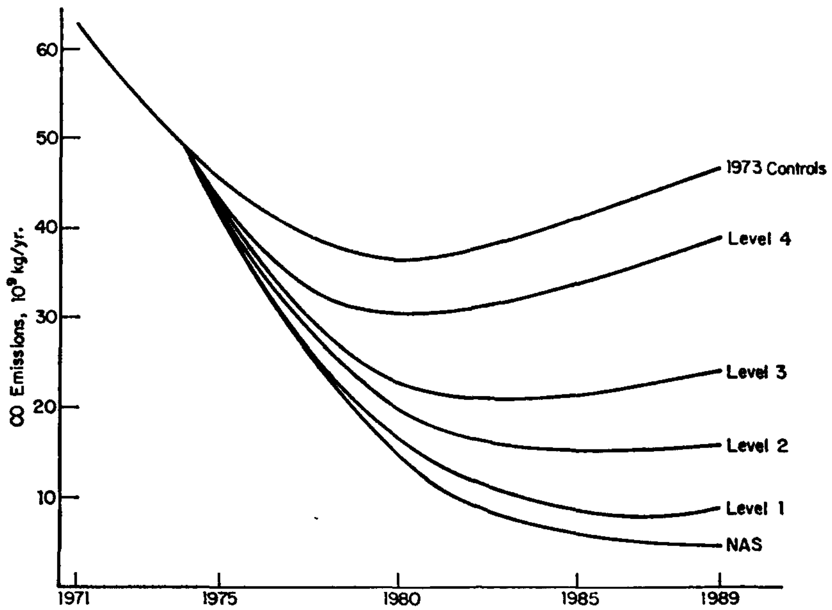

Figure 3. NATIONWIDE CARBON MONOXIDE EMISSIONS FOR ALTERNATIVE VEHICLE STABILITY LEVELS UNDER ESTABLISHED POLICY, WITH NO PROGRAM OF INSPECTION AND ENFORCED MAINTENANCE.

for each of the 15 years 1975–1989. The lowest curve in the figure duplicates an estimate prepared by the National Academy of Sciences [17] and assumes perfect stability in emissions (that is, zero deterioration of post-1975 vehicles). The top curve shows what would happen if emissions controls were left at 1973 levels. Other curves show total emissions with established policy (EST with no enforced maintenance) under alternative assumptions about stability. For example, the curve labeled "Level 4" results from established policy if, in fact, vehicles produced after 1975 deteriorate according to the definition of stability level 4 in Figure 2.

Several things are worth noticing about Figure 3. First, the effects of different policy options do not differ greatly in the early years (say, 1975–1979). This is because of the gradual turnover of the vehicle fleet. It takes several years before the tightly-controlled vehicles grow to be a significant portion of

[17] *Semiannual Report by the Committee on Motor Vehicle Emissions to the EPA* (Washington, D.C., January 1, 1972).

the auto population, and the results of any emissions control program play out over a decade or more. Another point to notice is that, unless emissions controls are highly stable, total emissions will be on the rise again in the late 1980s due to the growth in total miles driven. Finally, the figure shows that only the most optimistic assumptions (Level 1 or better) approach the goal of a 90 percent reduction in emissions sought in the Clean Air Act.

To the results for CO shown in Figure 3 must be added similar data for HC and NO_x, and for analysis of broad policy options these complex phenomena must be aggregated into an understandable set of summary indices. We aggregate pollutants by taking a weighted sum of total national emissions of CO, HC, and NO_x in each year.[18] Aggregation over time is accomplished by taking the simple sum of the weighted emissions over the 15-year period 1975–1989. The result is a set of estimates of the total tons of "pollutant" spewed out by cars under different policy options. Since we are concerned with the *incremental* reduction associated with the tightening of standards programmed for 1975 and 1976, we take the pollution that would be experienced under 1973 controls as the base condition. The percentage cutback achieved by a particular policy (below levels produced by 1973 controls) is termed its "Weighted Index of Reduction." This is our measure for comparing the effectiveness of the different policies laid out in Figure 1.

The values of the index for established policy are shown in the first column of Table 2. (The values for other policies are there as well; we shall return to them shortly.) As the table shows, emissions may be reduced, below those from 1973 controls, by as much as 55 percent or as little as 13 percent depending on the stability level attained.

The significance of such percentage reductions is not intuitively obvious, of course, for they are not measures of the things we value about pollution control – such as the health of human beings, plants, and animals.[19] One can, however, make very rough estimates as to what these reductions imply for current efforts to

[18] The weighting factors that lie behind the calculations presented here are $CO = 0.12$, $HC = 1.0$, $NO_x = 1.0$. The analysis was conducted using three distinct sets of weights, and the central conclusions proved insensitive to the weighting scheme used.

[19] A quantitative approach to this problem is provided by Ahern, *op. cit.*

Table 2. WEIGHTED INDICES OF REDUCTION IN EMISSIONS UNDER DIFFERENT POLICY OPTIONS, FOR INDICATED STABILITY LEVELS FOR ICE VEHICLES AND LEVEL 0 FOR ALTERNATE TECHNOLOGY.

Stability Level	*Weighted Index of Reduction, 1975–1989*				
	EST	*EST/ENF*	*REL*	*REL/ALT*	*EST/ALT*
1	.55	.59	.37	.51	.60
2	.45	.54	.11	.37	.55
3	.35	.47	–.15	.23	.49
4	.13	.34	*	*	.38

* Level 4 is not applicable under relaxed standards.

meet established ambient air quality standards. In a city such as Philadelphia, for example, where automobiles in 1967 contributed around 60 percent of CO pollution, an emissions control program experiencing poor stability (Levels 3 or 4) might result in 10 to 20 periods each year during which the 8-hour standard for CO concentrations was exceeded (i.e., 1–2 days per month).[20] If the ambient standards are accurately set, then adverse health effects would still be suffered even after 15 years of the control program.

The Role of Enforced Maintenance. Results like the above, which show the effect of technical instability on the degree of clean-up achieved, inevitably suggest the potential value of a program of inspection and enforced maintenance as a means of controlling the deterioration of emissions controls. No doubt the difficulties of establishing such a system on a national scale are formidable. Fifty states and countless local jurisdictions would be involved; few of them now possess legal authority to establish inspection and maintenance programs, much less the capacity to make them work. To build a program capable of controlling an unstable technology would not only require setting up (or supplementing) testing and inspection programs in 20 or 30 states at a minimum; it also would require regulation of maintenance facilities, licensing of mechanics, and so on. And since all of this would entail significant harassment of motorists, such a program would be hazardous politically. In short, it is questionable that

[20] This would occur in 1985–89 assuming Level 3 or Level 4 stability under the established policy, normal weather and traffic conditions, and a 50 percent abatement of stationary source pollution. For further detail on such calculations see Ahern, *op. cit.*

a comprehensive enforcement system can be created, or that if it were created it would operate efficiently.[21]

Still, a maintenance program is an important part of control policy as conceived in the Clean Air Act, and it deserves careful attention. There are many ways such a program could be organized — some more effective in reducing emissions than others. The format most likely to be adopted involves state-run inspection stations which try to identify high emitters and send them to certified private garages for restoration of their air quality control systems.

California and New Jersey are the only states that have attempted inspection programs to date. Following their experience, the measured emissions rate at which cars will fail the test probably will be set by most states in such a way that some predetermined percentage of all vehicles will be selected out as high polluters. No state administration wants a system that fails so many cars as to be politically unacceptable or so few that it appears a waste of time. Furthermore, the test criteria are likely to be designed so that the percentage failed is roughly the same for all model years. It would be hard to sustain a program that penalized the owners of old cars and let new car owners go free — or vice versa.

Based on these assumptions about what states will in fact do if they are induced to set up inspection and service programs, an evaluation has been prepared for a national system that fails 30 percent of the cars each year. Cars receiving the mandated service under this program are considered to be restored to the level of emission control they exhibited as new vehicles. That is, the emissions of cars failed are forced back to the lowest point on the appropriate stability curve in Figure 2.[22] Such assumptions are

21 It is argued that enforcement ought to be selective by local area according to the severity of the air pollution problem. Montpelier, Vt., would allow its motorists to gain the benefits of lax controls, while Los Angeles would impose a vigorous enforcement program, perhaps even requiring a different vehicle design. Regionalization is attractive if there are only a few areas requiring stringent controls, but unfortunately Los Angeles and Philadelphia are not the only cities with serious problems. A study by the Office of Science and Technology concludes that 70 percent of the vehicle population would require controls; see *Cumulative Regulation Effects on the Cost of Automotive Transportation* (RFCAT; Washington, D.C., February 28, 1972). If the vehicles that must be rigidly controlled constitute a significant portion of the population (say, 40 percent or more), then this analysis of a national program holds for a regionalized program as well.

22 The level of stability is assumed to be inherent in the technical design and

extremely favorable regarding the effectiveness of maintenance and obviously represent the outer bound of what can be expected.

This version of the established policy with enforcement on the road is given the shorthand name EST/ENF, and the Weighted Indices of Reduction under these conditions are shown in the second column of Table 2. These data, which present a picture purposefully biased in favor of maintenance programs, bring out the fundamental dilemma inherent in this policy instrument. Under highly stable conditions, where the maintenance cannot produce a substantial reduction in automotive emission because there is none to be had, an enforcement program does not add a great deal to effectiveness. Under low stability conditions (say Level 4), enforced maintenance does raise effectiveness, but the ultimate improvement over 1973 controls is still not very great.

Program Costs. Estimating the costs of the different policy options for emissions control is, of course, an exercise in making reasonable assumptions. Until controlled automobiles are mass-produced and driven under road conditions, the actual cost of emissions control cannot be known. Even then accurate cost calculations will require an elaborate effort not likely to be undertaken. It is important, therefore, to impose the proper structure on the problem and to provide a range of possible estimates reflecting the inherent uncertainty.

The discussion above identifies four components of cost: (1) the increase in vehicle manufacturing cost, (2) the increased cost of vehicle maintenance, (3) the decline in fuel economy, and (4) the cost of inspection, specialized air quality control service, and general administration necessary to enforce performance on the road. Table 3 presents low, medium, and high estimates of the 15-year total of these costs under current policy. The low estimate assumes an increment in manufacturing cost over that of 1973 vehicles of only $100. This is extremely optimistic, as it is well below the current official estimates shown in Table 1. The estimated fuel penalty, at 5 percent, is also at the low end of most estimates.

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thus cannot be changed, though a maintenance program can hold actual emissions rates below the maximum values. It is possible, of course, that harassment of motorists on the road may reverberate back to the design labs in Detroit, and that a rigid enforcement program could lead to more stable vehicles at some point in the future. It is argued that this linkage is very weak.

Table 3. LOW, MEDIUM, AND HIGH ESTIMATES OF 15-YEAR PROGRAM COSTS UNDER ESTABLISHED POLICY, AT A 5% DISCOUNT RATE.

Cost Assumptions	*15-year Program Cost* ($ billions) *No Enforced Maintenance (EST)*	*15-year Program Cost* ($ billions) *With Inspection and Enforced Maintenance of 30% of Vehicles (EST/ENF)*
Low Cost Initial Cost = $100/car Regular Maintenance = $10/car per year Fuel Penalty = 5%	27.4	40.5
Medium Cost Initial Cost = $250/car Regular Maintenance = $20/car per year Fuel Penalty = 10%	61.5	74.6
High Cost Initial Cost = $400/car Regular Maintenance = $20/car per year Fuel Penalty = 20%	94.0	107.1

The medium cost estimate represents, in effect, the results of most of the official government studies of control system cost. The high estimate is consistent with the figures released in most industry analyses of manufacturing expenses, and the more pessimistic predictions about fuel economy.

One implication of these estimates is immediately evident. If $30–100 billion is to be spent on controlling automotive emissions, then the government surely ought to think broadly about its policy options. With that amount of money at stake, even very substantial changes in the current manufacturing process can be considered; even very risky investments in technical development can be justified.

Possible Failure of Prototype Tests. In addition to the question of stability and the problems of enforcement, there is also a significant possibility that the automobile manufacturers simply will not be able to pass the prototype test with their 1976 model vehicles. To date none of the U.S. manufacturers has reported systems which meet all three standards under the established certi-

fication procedure. Should this situation hold into mid-1973, or if a one-year extension is granted, into mid-1974, then there will be an absolute confrontation over the established policy. The government will be legally committed to the standards; the industry as a practical matter will only be able to market vehicles which do not meet the standards. If it comes to that impasse, it is clear that some adjustment of the policy will be required, for no government could stand the pressure that would attend a halt in production even by a single manufacturer, much less the whole industry. The negative economic effects resulting from such an event would completely overwhelm the benefits to be gained from pollution reduction, and the political response would be commensurate with the stakes at hand.

Relaxed Standards

Some observers look at the manufacturers' complaints about cost and technical difficulty, and the risks for the government, and conclude that the standards should simply be relaxed. There is uncertainty and hence disagreement about the precise degree of relaxation needed to avoid these problems, but a reasonable approximation would set new standards at 8.5 gm/mi CO, 1.0 gm/mi HC and 1.0 gm/mi NO_x. These standards would represent a 75 percent reduction in emission rates, as opposed to the 90 percent called for in the act. This option is denoted as REL in Figure 1, and the associated values of the Weighted Index of Reduction are presented in Table 2.

Such relaxed emission rates probably could be met with control techniques currently under development, and the trade-offs would not be as severe as under current standards. Though higher at the outset, such emission rates should be more stable. There would still be some EGR but less of it, and no reducing catalyst. There might be an oxidizing catalyst but with a lower required removal rate it should be more durable. Other adjustments would be less severe, and this leeway would allow designers to gain back road performance, driveability, and fuel economy — and at reduced cost.

The degree of cost reduction is uncertain, and so once again

Table 4. LOW, MEDIUM, AND HIGH ESTIMATES OF 15-YEAR PROGRAM COSTS UNDER RELAXED STANDARDS, AT A 5% DISCOUNT RATE

Cost Assumptions	*15-year Program Cost* ($ billions)
Low Cost	
Initial Cost = $75./car	
Regular Maintenance = $5./car per year	13.9
Fuel Penalty = none	
Medium Cost	
Initial Cost = $150./car	
Regular Maintenance = $5./car per year	30.2
Fuel Penalty = 5%	
High Cost	
Initial Cost = $250./car	
Regular Maintenance = $10./car per year	53.7
Fuel Penalty = 10%	

we develop a set of three cost estimates that span the range of likely outcomes. Table 4 shows a low estimate that assumes an incremental cost of only $75 per car over 1973 models and no fuel penalty whatsoever. The high estimate is very similar to the medium estimate for the existing policy. This is not unreasonably high, since most of the equipment required to meet established standards will be needed to satisfy the relaxed emissions ceilings.

A central argument for relaxation of the standards, mentioned earlier, asserts that most of the benefits of automotive emission control can be achieved with a lesser reduction than that now being sought. Thus even if the relaxed standards do result in increased emissions, it is argued, pollution is still going to be controlled to levels where this small increment to air pollution will not be very damaging, and is certainly less important than the cost savings it would enable.[28]

Though a relaxation of the standards would draw strong political attack, a serious rationale can be constructed. After utilizing the very tight standards of the Clean Air Act to drive the industry to a serious commitment to emissions control, this policy then steps back and sets new standards utilizing the information that research has made available. Such an adjustment can be por-

[28] A strong statement of this view is to be found in the RECAT study, *op. cit.*

trayed as a reasoned balance of competing claims. In that it probably would enable all manufacturers to pass the prototype test, this option also avoids the danger of provoking a sharp political confrontation on the issue.

The problems with relaxed standards arise from the fact that such a policy would stabilize pollution at higher levels than the current approach. Unless gains in stability from the relaxed standards were very dramatic, they would not compensate for the higher emissions rates. More important, in relaxing the pressures on the industry, the REL option would even further reduce interest in a stable, low-polluting alternative to the ICE. Natural deadlines for subsequent reassessment of policy would be removed, and the legal viability of current technical approaches would be assured. Hence the current control program would quickly become established and difficult to adjust. In short, a policy of simply relaxing the emissions standards forfeits flexibility.

Alternative Technology

Several of the alternatives discussed earlier offer stable low-polluting engines with no insurmountable disabilities inherent in the technology itself. (Of course it will cost time, money, and political energy to make a change, and there are side-effects to consider.) The argument for changing the technical basis of the emission control program to an advanced engine technology rests upon two propositions. The first is that the technical trade-offs now plaguing control of the ICE are not likely to be drastically eased by the discovery of some supergrade catalyst — the holy grail of the piece. The second is that, whether out of considered rational judgment or sheer political will, the nation will in fact insist on the objective of 90 percent abatement now embodied in the Clean Air Act and will therefore hold to the current emission standards. If these propositions be true, the shift to alternative technology would be both necessary (to achieve the objectives) and economically wise (to avoid the high fuel, maintenance, and enforcement costs of an unstable technology).

Since data on alternative technologies are even more uncertain than those for current technology, we will not attempt to make

direct estimates for the various propulsion systems discussed above. Rather let us define an alternative technology option as one that achieves Level 0 stability for an incremental manufacturing cost (including R&D and retooling/retraining costs) of $500 more than the ICE with 1973 controls. Since the hypothetical technology is stable, no excess maintenance cost is levied (in fact most options would provide actual savings in maintenance and replacement). Fuel costs are assumed to be the same as for the gasoline-powered ICE (even though most of the technical alternatives run on cheaper fuels). These assumptions about operating cost appear reasonable, or even pessimistic, for Rankine cycle and stratified charge engines. And thus we establish an *a fortiori* argument. If the abstractly defined advanced technology compares favorably with the current control strategy even under this harsh assumption about manufacturing cost, then the more moderate costs that are very likely to be associated with a real alternative can only enhance the attractiveness of a new approach.

Since we are assuming that none of the alternative technologies can be prepared before the model year 1981, there would have to be some interim program under this option. There are two obvious possibilities. The government could hold to the established standards, force the industry to install the ICE control devices now contemplated, and simply tolerate the resulting instability during the 1975–1980 period. We have labelled this option EST/ALT to designate its components. Responsible officials might choose to do this to maintain the political integrity of the program, to gain the benefits of slightly lower pollution, or both. It is even conceivable that the EPA might not halt sales of model lines that came close to the standards but somehow failed to pass the rigid prototype procedure — substituting instead a set of nonprohibitive fines for noncompliance during the interim period.

The second possibility would be to relax the emission standards during the interim period to reduce costs and to help shift Detroit's attention to preparing new technology. This option is labeled REL/ALT after its components.

Fifteen-year program costs for the two advanced technology options differ by virtue of different cost estimates which can be made for the interim program. For each alternative we project

Table 5. LOW, MEDIUM, AND HIGH ESTIMATES OF 15-YEAR PROGRAM COST WITH A SHIFT TO ALTERNATIVE TECHNOLOGY IN 1981, AT A 5% DISCOUNT RATE

	15-year Program Cost ($ billions)	
Cost Assumptions	*Established Standards 1975–80 (EST/ALT)*	*Relaxed Standards 1975–80 (REL/ALT)*
Low Cost	51.3	44.1
Medium Cost	68.0	52.0
High Cost	83.7	63.5

low, medium, and high program costs reflecting various assumptions about the interim period. These are presented in Table 5.

There is a formidable difficulty with the alternative technology option: A large number of people will have to change their hearts and minds about what type of equipment belongs under the hood of a car and what kind of research and development the federal government should engage in. The automobile manufacturers, who are doing well with the ICE, are not destined to respond with deep enthusiasm to a program which forces them into a major reorientation of plant capacity on behalf of a project whose central effect is likely to be to localize more of the cost of emission control at the manufacturing stage. To get serious development of alternative technology within the industry, the government would undoubtedly have to play a major financial role in the research and development process – as they have in other areas of the economy. This would require major changes in the habits and policies of critical agencies of the government – particularly the Congressional subcommittees dealing with pollution issues and the Office of Management and Budget, both of whom have opposed such a governmental role.

This option, moreover, would inevitably expand the scope of the policy into the problems of managing energy resources. The established policy itself will have a major impact on oil consumption, and will add a significant amount to our balance of payments deficit in the late 1970s and 1980s.[24] The process of adopting

[24] At a 10 percent fuel penalty, which is in the mid-range of the estimates shown in Tables 1 and 3, the addition to oil imports could amount to $1 billion or more by the late 1980s. This would require an additional 200,000-ton supertanker arriving at a United States port every other day!

one of the alternative technologies, however, would be lik to change the basic pattern of energy consumption. Since automotive transportation represents a significant portion of over-all energy use, it would be unwise to embark on a shift in automotive technology without a much more thorough analysis of the energy implications than is now available.

Evaluation of the Options

Figure 1 provides a schematic summary of the basic policy choices and the two key outcomes, cost and stability, that determine their relative attractiveness. Unfortunately, it will be five or more years before it is known for certain which branch best describes the cost of any policy decision, and it will be a decade before the stability characteristics of controlled vehicles (and therefore the ultimate pollution levels) are fully known.

In this kind of uncertain situation, one very informative approach to evaluation is to look at the *expected* outcome in terms of cost and on-the-road emissions. Estimates of costs and vehicle stability have been developed above which span the range of possible outcomes. It is possible to make some reasoned judgments about how likely these outcomes are – although, of course, different observers may disagree. By combining the estimates of effects and their relative likelihood, one can develop estimates of the characteristics of the expected outcome for each policy, and these data should prove informative in deciding between them.

Two estimates of the expected outcomes of the policy options are presented below. The first is based on our own estimates of the evidence available to date, and is asserted to be a "reasonable" evaluation of the different options. Then, to test the sensitivity of the conclusions, estimates are presented which represent unabashed optimism about the future of emissions controls on the conventional ICE. The point of the exercise is to show that the conclusions are the same over very wide ranges of disagreement about probable costs and stability.

Reasonable Assumptions. Reasonable assumptions about the likelihood of various outcomes are displayed in Table 6. For each of the policies, two sets of assumptions must be made: (1) what is the probability that 15-year program cost will be nearest

Table 6. EXPECTED OUTCOMES OF ALTERNATIVE POLICY OPTIONS UNDER REASONABLE ASSUMPTIONS ABOUT THE RELATIVE LIKELIHOOD OF DIFFERENT LEVELS OF COST AND VEHICLE STABILITY

Policy Option	*Program Cost*		*Probability of Stability Level for Given Cost Level*				*Expected 15-Year Program Cost* (\$ billions)	*Expected Weighted Index of Reduction 1975–89*	*Expected Weighted Emissions 1985–89 as fraction of 1971 Levels*
	Level	*Probability of Level*	1	2	3	4			
	Low	.25	.1	.4	.4	.1			
EST	Medium	.50	.1	.4	.4	.1	61.1	.39	.69
	High	.25	.1	.4	.4	.1			
	Low	.25	.1	.4	.4	.1			
EST/ENF	Medium	.50	.1	.4	.4	.1	74.2	.50	.79
	High	.25	.1	.4	.4	.1			
	Low	.25	.1	.4	.4	.1			
EST/ALT	Medium	.50	.1	.4	.4	.1	67.8	.51	.88
	High	.25	.1	.4	.4	.1			
	Low	.25	.5	.5	.0	.0			
REL	Medium	.50	.5	.5	.0	.0	32.0	.24	.55
	High	.25	.5	.5	.0	.0			
	Low	.25	.5	.5	.0	.0			
REL/ALT	Medium	.50	.5	.5	.0	.0	52.9	.44	.85
	High	.25	.5	.5	.0	.0			

our high, medium, or low estimates, and (2) given that the cost came out at a particular level, what is the probability that vehicle stability will turn out to be Level 1, 2, 3, or 4? From these assumptions, and the data presented in Tables 2 to 5, the expected level of cost and the expected Weighted Index of Reduction can be calculated. We also calculate an indicator of the emissions in the period 1985–1989 in relation to 1971 levels. The results are shown in the three right-hand columns of Table 6.

Consider the assumptions for the established policy, EST, for example. Trying to be reasonable, we assume there is only a 25 percent chance that the cost will be around the high estimate in Table 3, and a 25 percent chance of the low figure's coming about as well. By implication, there is a 50 percent chance the medium estimate is the correct one. These assumptions give a present value of expected cost for the fifteen years of $61.1 billion (using a 5 percent discount rate). Regarding stability, we assume there is only a 10 percent chance that controlled vehicles will be as stable as Level 1, and similarly a 10 percent chance that the program will produce vehicles as poor as Level 4. The result is likely to be somewhere in the middle, and we assume a 40 percent chance of Level 2 and a 40 percent chance of Level 3.

In this particular calculation, the likelihood of different stability levels is assumed to be independent of the cost of the program. As the layout of the table and of Figure 1 imply, more complex assumptions are possible. It may be, for example, that if the cost turns out to be at the high end of the range, then the vehicles would be expected to be more stable than if costs are low. (One also can argue the opposite.) Based on information available to date, however, the assumptions in Table 6 appear to be the most reasonable, and for policy EST they result in an expected value of .39 for the Weighted Index of Reduction.

The last column of Table 6 presents a rough estimate of the degree to which the current objectives of the Clean Air Act would be achieved under the various policy options. It gives the weighted reduction in all three pollutants, stated as a fraction of their 1971 levels, the reference point of the act. The measure is calculated for the 1985–1989 period to see the results of each option after a decade — long enough to achieve the full degree of control inherent in the policy. Under the assumptions just presented the

established policy would yield a 69 percent reduction in this period — still around 20 percent short of the objective.

Next, the table shows the same analysis for a program with enforced maintenance, EST/ENF. The relative likelihood of different levels of cost and stability are assumed to be the same for established policy, and once again the table shows the expected costs and effects in the right-hand columns. Two points are worth emphasizing about the analysis of a maintenance program. First, by assuming that the probability of different stability levels is the same as for a program without maintenance (.1,.4,.4,.1), we essentially assume that the manufacturer's basic vehicle design is not significantly influenced by the maintenance program. (Of course, cars spend less time in the higher emitting state and therefore pollute less, as indicated by the increase of the Weighted Index of Reduction from .39 for EST to .50 for EST/ENF.) And second, by assuming a maintenance program that essentially makes cars like new, the analysis is based on *extremely* favorable assumptions about the performance of the service sector. On balance, the second is by far the more significant bias, and if anything the analysis is tilted *in favor* of maintenance schemes. This should be kept in mind in assessing the results and conclusions.

Table 6 also presents assumptions for EST/ALT, and the resulting performance indicators. Regarding costs, recall that the probabilities shown are for the cost of controls during the 1975–1980 period only, and that the cost of vehicles powered by the alternate low-polluting technology has been set at a high level throughout the analysis. Thus the analysis purposefully is biased *against* the options involving advanced technology, and once again this should be kept in mind when considering the conclusions.

Finally, the table presents analyses of solutions based on relaxed standards: the case with relaxation (REL) and the option involving relaxation coupled with a shift to alternate technology (REL/ALT). The calculations for these options incorporate assumptions about gains in stability with relaxation in the emissions standards mandated for 1975 and 1976. We assume there is no chance whatsoever that stability will be as bad as Levels 3 or 4, and that there is about a 50 percent chance that stability may be as good as Level 1. If anything, these are optimistic assumptions about vehicle stability under the relaxed emissions controls.

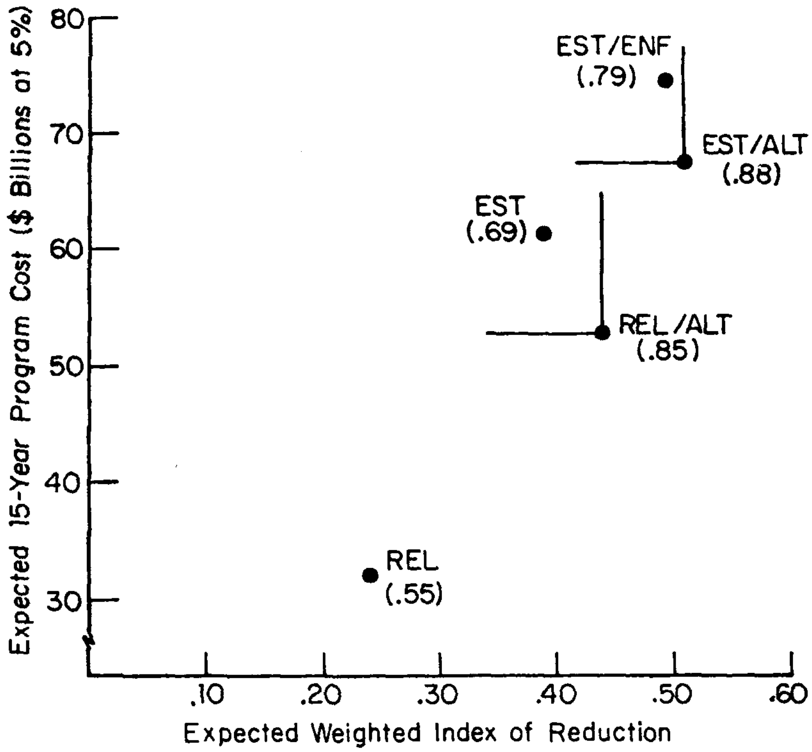

Figure 4. EXPECTED OUTCOMES UNDER ALTERNATIVE POLICY OPTIONS FOR REASONABLE ASSUMPTIONS ABOUT PROGRAM COST AND STABILITY OF VEHICLE EMISSIONS (TABLE 6).

In order to discuss these results it is helpful to represent the data in the last three columns of Table 6 in graphical form. This is done in Figure 4. Each of the five policy options is plotted with cost on the vertical axis and emissions reduction on the horizontal. The numbers in parentheses show the emissions reduction achieved by the 1985–1989 period, stated as a fraction of 1971 levels. The best place to be on this diagram is as far down toward the lower right-hand corner as possible, for movement in that direction means more clean-up at less cost.

The results are striking. First of all, the option of relaxing standards and switching to alternate technology clearly dominates the current policy. It provides a greater expected reduction in emissions over the 1975–1989 period, and at an expected cost saving of around $8 billion in present value terms. It also more

closely approaches the 90 percent objective. It is better in every dimension, and recall that the cost analysis is purposefully biased *against* alternative technology.

What about enforced maintenance? As Figure 4 shows, the option EST/ENF does achieve a greater emissions reduction, at a price. But, once again, this policy is dominated by the option with established standards for the 1970s and a shift to alternative technology in the early 1980s. EST/ALT has a higher expected Weighted Index of Reduction and an expected cost advantage of over $6 billion.

The relationship between EST/ENF and REL/ALT is not one of dominance, but the clear preference between the two is for REL/ALT. It achieves tremendous cost savings (around $20 billion) with only a small (4 percent) loss in pollution reduction over the 1975–1989 period.

At this point let us pause to draw the obvious conclusion. The established policy, either with or without maintenance, is dominated by options involving alternative propulsion technologies. Hence to the extent that this framework of assumptions holds, there is a clear advantage to the economy and to the breathing public to prepare for this shift. Today, the federal government's annual expenditure on alternative propulsion technology is around $5 to $8 million per year. The expected cost saving, in present value terms, of a shift to a clean alternative is *a thousand times* that amount – and with clearer air.

The analysis also strongly indicates that large-scale systems of vehicle inspection and enforced maintenance are not a good idea, even under very optimistic assumptions about their performance. The difficulties and high cost of regulating one hundred million individual motorists are so great that it is evidently better to insist on a stable, clean vehicle to begin with – even at some considerable cost in development and manufacturing.

What about relaxing standards to save money? The saving is great, as Figure 4 shows, but so is the increase in emissions. This, even with very optimistic assumptions about stability gains with a loosening of controls. The expected value of the Weighted Index of Reduction is only .24, and expected total emissions at the end of the 1980s represent only a 55 percent reduction below 1971 levels. One can argue at great length about the validity of

ambient air quality standards and the true health damage from automotive emissions, but it would be our judgment that the nation is unlikely to accept this result, which after 15–20 years of effort would still leave a palpable air pollution problem in many areas of the country.

The choice between REL/ALT and EST/ALT is more difficult. Between the two there is a trade off between cost and cleanup; neither one dominates the other. The incremental cost of the additional reduction to be gained by the movement from REL/ALT to EST/ALT is high, as might be indicated by the slope of a line drawn between the two points. On the other hand, there is an argument in favor of EST/ALT that is not captured by this analysis based on the expected values of costs and emissions. The analysis assumes that the transition to alternative technology can actually be brought about — which, of course, it would be if the problem were taken as a major national priority. But if there is a chance that Detroit might successfully resist a proven alternative technology, even if it were clearly superior from a public point of view, then REL/ALT and EST/ALT differ greatly. Under the REL/ALT option, if the advanced technology is not actually marketed, then you get the result that relaxed standards would produce. To stick with the established standards during the interim period, while an alternative is being prepared, is a hedge against a failure in implementation at a later stage.

Optimistic Assumptions. What if one thinks that the assumptions in Table 6 are too conservative, and that it is much more likely that current efforts will succeed, and that the technical trade-offs inherent in the ICE will be broken? For the true believer, we recalculate the estimates using assumptions that should satisfy the most optimistic observer. The data shown in Table 6 are revised to reflect the assumption that under current policy there is a 70 percent chance that vehicle stability will be as good as Level 1 and that the chance of stability being at Level 2 or better is around 90 percent. Furthermore, we assume that if standards are relaxed there is a 90 percent chance of getting Level 1 stability.

No doubt these are incredibly optimistic assumptions. Yet the conclusions we drew from the former, more reasonable, set of assumptions are unaffected. Figure 5 presents the plot of results.

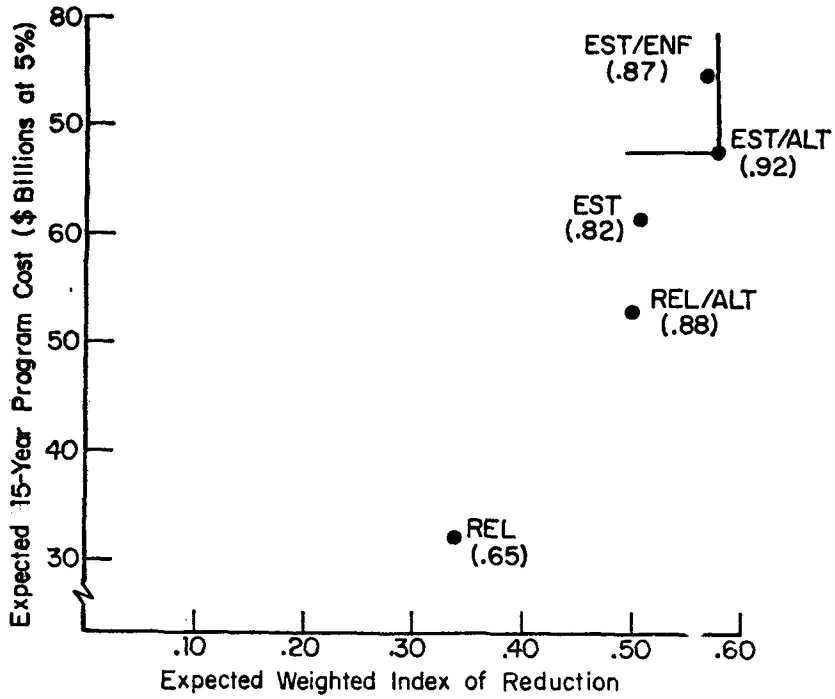

Figure 5. EXPECTED OUTCOMES UNDER ALTERNATIVE POLICY OPTIONS FOR REASONABLE ASSUMPTIONS ABOUT PROGRAM COST AND EXTREMELY OPTIMISTIC ASSUMPTIONS ABOUT VEHICLE STABILITY.

Once again the policies involving alternative technology (REL/ALT and EST/ALT) are clearly superior to the two versions of established policy. EST/ALT dominates EST/ENF, as before (that is, it is better in both dimensions). REL/ALT no longer dominates established policy (EST) because the expected Weighted Index of Reduction for the EST policy is now better. But it is only very slightly better (one percentage point). So even with extremely optimistic assumptions about the stability of controlled ICE-powered vehicles, the advantages of a shift to alternative technology remain clear (though, of course, less dramatic than under more reasonable assumptions about expected stability).[25] The

[25] Once again, it is possible to make still other assumptions about stability, although it strains the imagination to consider assumptions more favorable than those behind Figure 5. And one could make alternative assumptions about the relative likelihood of different cost levels, although it would, as argued earlier, take basic revisions in the entire framework to threaten the results arrived at here. For the

policy of simply relaxing standards (REL) still looks unacceptable.

On balance the established policy appears to be on the wrong track. Even with the assumptions loaded in its favor it cannot be expected to meet the objectives of the Clean Air Act and is not an efficient solution for the over-all economy. Moreover, this situation cannot be remedied by rigorous implementation of the enforcement provisions now set forth in the legislation. The attempt to crack down on an inherently unstable technology with elaborate enforcement procedures would be an immensely expensive exercise in frustration.

If, as now appears to be the case, the government is serious enough about its objectives to contemplate gasoline rationing in Southern California and severe traffic controls in the nation's capital, then it ought to be serious enough to attend to the basic flaws in the regulatory machinery. The standards and deadlines are producing a highly questionable technical approach to emission control. At a bare minimum, serious effort ought to be devoted to preparing a more appropriate technology.

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reader who wants to try his own estimate, all the necessary data are provided. The costs are shown in Tables 3, 4 and 5; the effects are laid out in Table 2. Following the format of Table 6, one can try any set of assumptions he wants and see how the answers come out.

Since the article was published the price of oil has risen dramatically, the security of its supply has been threatened, and the Nation's concern for efficiency in the use of fossil fuels has increased accordingly. In addition, there has been a great deal of technical discussion about the desirability of maintaining the very strict NO_x standard set under the Clean Air Act Amendments. I would like to argue that these recent developements on balance strengthen rather than weaken the original argument, that the Federal Government must play a critical role in bringing about the desirable technical development, and that with some qualification H.R. 10392 provides a promising means.

The essential point, I believe, is to realize that the most serious difficulties in developing alternative automotive propulsion systems are technical or even strictly economic. They are organizational and political. Let me elaborate on that theme.

When my colleagues and I began our review of the problem of automobile emission control in early 1971 we immediately observed that the automobile manufacturers were conducting very large research efforts but that they were focusing these efforts in a very unpromising technical area. They were attempting to control the basic internal combustion engine (the ICE in the vernacular of the trade) by using catalytic devices in the exhaust steam and by a number of changes in the combustion process requiring relatively rich air-to-fuel ratios. With this kind of technology the manufacturers faced severe trade-offs between some basic engine parameters; namely, (1) HC and CO emission rates, (2) NO_x emission rates, (3) fuel economy, and (4) power output and stability of the engine. We observed that it would be possible to diminish these trade-offs by using substantially different engine technologies—Rankine cycle, elective drive, stratified change, and the use of gaseous fuels are readily identified as promising alternatives. The companies were not conducting a very serious research effort in these broader areas, however, as measured against their primary focus, and as a result the technical response to the Clean Air Act promised to be a very unhappy one. That judgment is substantially corroborated by the Committee on Motor Vehicle Emissions of the National Academy of Sciences.[1]

There are a number of reasons why the manufacturers have responded to the Clean Air Act in a way which seems quite unfortunate when judged from the perspective of public policy:

(1) Apart from its emissions and now fuel consumption, the ICE is a very successful engine well adapted to the American market. Its disadvantages (this is, social costs) are, in the economist's sense, external to the market in which the manufacturers operate.

(2) The automobile companies—particularly the leader General Motors—have habitually made rater low investments in basic research and technology and have concentrated instead on production efficiency and marketing.

(3) In order to control variation in short-term sales the manufacturers strongly prefer to constrain the pace of technical change—making only marginal changes in basic technology from year to year. The market is a tacitly organized one. Severe depressions in short-term

[1] Report by the Committee on Motor Vehicle Emissions, National Academy of Sciences, Washington, D.C., 1973.

sales lasting more than a couple of years could lead to the failure of one or both of the marginal firms and theoretically could precipitate antitrust action against General Motors. Whether realistic or not that scenario is feared in Detroit.

(4) Internal financial control procedures—particularly in General Motors—make it virtually impossible for division managers to undertake serious research and development investments which will not produce a financial return within 2 or 3 years. This excludes most if not all of the broader technical options.

(5) The central technical centers where research on advanced power systems has been undertaken are deliberately kept separate from the product divisions which actually produce and market vehicles. The technical centers cannot initiate a product line and their research has served mostly to monitor possible long-range technical competition.

(6) The deadlines imposed by the Clean Air Act were strict enough that most of the technical community conceded that it would not be possible to meet them with anything but an ICE based technology. Thus the particular character of the Clean Air Act reinforced the basic tendency of the industry.

In order to overcome these fundamental forces for technical conservatism I believe that it is both necessary and proper for the government to perform two functions: (1) to absorb some of the risk involved in long-range technical investment—as it has done for other sectors of American industry and (2) to play a critical but temporary role in organizing a shift of the market to a new technology. Let me comment briefly on H.R. 10392 in these terms.

First there is the matter of money. I think it is important to realize that much of the basic research in this area has already taken place. Although there is a great deal yet to be learned, the problem is more than that of moving from research prototypes to marketable vehicles than of making technical breakthroughs. As the members of this committee well know, development costs tend to increase dramatically at the advanced stages. The major American manufacturers—General Motors, for example—seem to be spending well into the hundreds of millions of dollars a year on their current, highly focused efforts directed primarily at emission control. Presumably, a more radical effort involving a complete vehicle redesign would cost more. Also, though cost estimates vary widely, it seems clear that the emission control effort will cost the American economy many tens of billions of dollars over the 15-year period from 1975 to 1990.[2] The difference in the efficiency of alternative technologies can be expected to be the tens of billions as well. In this context the $30 million authorization included in this bill seems very small indeed. Assuming that it was not arbitrarily chosen—that it is a politically palatable figure—it frankly seems to me to be a sign that the government still has not grasped the magnitude of the problem that it is dealing with.

The second issue, the matter of direction, is more subtle, and here the virtues of H.R. 10392 would depend very much on how NASA implements its mandate. It is a reasonable axiom of this business that for the foreseeable future whatever automobile is produced for the American consumer will be produced by the four major American manufacturers

[2] These figures discounted to present value in 1975. The 15-year period roughly reflects the minimum life of a basic technical choice in the automotive area.

who have generally controlled over 80 percent of the market. Neither foreign competitors nor—more remotely—new entrants into the market can fundamentally change this fact. The problem therefore is that of inducing these particular, very large organizations to undergo a more fundamental technical change than is likely to happen naturally. The issue is in the product divisions of the major companies; it is their technology which must change, their design and production process which must be preempted. I believe that if the problem is to be solved the current manufacturers will have to undertake most of the advanced development work themselves and that all of them will have to make substantially the same technical choices under substantially the same time schedule. They cannot legally or practically do this under current competitive arrangements. The role of the Government—and of NASA if it is to be the Government's agent—is to aid in the technical choice, but even more to act as coordinator, to insure that technical developments have integral production and marketing plans, to referee an orderly transition.

The questions I would raise, then, are clear. Can NASA conceive of itself in this kind of a role? Can it effect the necessary change in its industrial clients? Can it conduct the program on a temporary basis and withdraw from active involvement once the transition has been effected? Would Congress as a whole affirm such a program? I do not have answers to these questions. I am predisposed to believe that positive answers are possible but I think a realistic appraisal is necessary.

Since the approach I have sketched out raises hackles in some quarters let me try to introduce and briefly answer a few prominent objections and perhaps provide a lead for your questions.

First, I have academic colleagues who argue that the Government should confine to general regulation and should not become involved in details such as the choice of a specific automotive technology. Under the proper incentives, they argue, the market will find the optimal technology and they suggest setting incentives such as graduated taxes on emission and fuel consumption. Though I favor such incentives, I do not think they are adequate in and of themselves. The automobile companies are very large, very complex organizations who do not simply and neatly behave like economic maximizers. Since large issues of public consequence are at stake in their technical decisions I believe it is appropriate for the Government to monitor those decisions in detail, and I do not believe that such activity vitiates the advantages of market competition.

A second objection is that the emissions standards—particularly the NO_x standard—are unreasonably restrictive and that an adjustment of the standards will allow cost and efficiency gains without the great effort required to change technology. Those who make this point naturally enough point to the current problems of energy supply and argue that we should now value efficiency in fuel consumption relatively more and emissions control relatively less. This is a question which turns upon relative magnitudes. Without engaging in a long technical discussion let me make a summary rejoinder. Even granting the various adjustments of the NO_x standard which have been publicly defended in any objective detail, the standard would lie in the range 0.8 to 1.5 grams/mile and the most reasonable standard probably would fall in the area of 1.0–1.2 grams/mile. This is still restric-

tive enough to cause serious difficulty for the ICE and to put a considerable burden on efforts to achieve gains in fuel economy. The effect of the energy crisis it seems to me is to give even greater weight to the overall objective of achieving a fundamentally more favorable technology, one which does not impose such severe tradeoffs between emissions control and fuel efficiency. Our current difficulties in insuring gasoline supply at reasonable prices give all the more reason to contemplate quite seriously a basic change in automotive technology, difficult as that process might be.

Let me just say very briefly, parenthetical to my statement that I talked about NASA in the statement as the agent of the Government's role. I realize that is probably not what the authors had in mind. You had more in mind having NASA undertake basic technical development, and I understand that. I said what I did to emphasize that I really do think the problem is at advanced stages of development and that NASA is a conceivable locus for this job. NASA's great advantage is that it does have both congressional and broader public trust as a technical agency. Perhaps no other agency in the Government can match its technical reputation. I do believe that the problem here is achieving a technical consensus within the country as to which of the contending technologies really ought to be chosen. I think that is a very difficult problem. We do not have anything like a consensus at the moment. I think that the one agency which might be able to achieve that would be NASA. On the other hand, it would require, I believe, that they free themselves from primary identification with gas turbine engines. As to whether they can really do that, I leave the question to you.

Mr. Brown. Thank you very much, Dr. Steinbruner.

I wish that the Congress had the ability to view objectively and achieve solutions to problems in the same way that Harvard does. I am afraid we are far from that.

Do you have any questions, Mr. Symington?

Mr. Symington. Thank you, Mr. Brown.

I compliment you on your statement, as well. You state that the auto companies because of their product line approach to problem solving must take the lead in developing the innovative process to alternative modes. I think you may be hinting that they ought to be relieved of some of the antitrust implications of this kind of a search so a coordinator from the outside could assist them in joint efforts.

Are you suggesting that?

Dr. Steinbruner. No; I think that is slightly off of what I meant to say. I stated they have historically not been technically innovative. You can't really expect them to be. The technical innovations are all about you, as you have seen from the parade of witnesses before this committee. Nonetheless, the major companies are the ones who will, in fact, mass produce automobiles for the American market. If you are going to enact either emission controls or serious efficiency gains you must change their technology; that is where the ultimate problem is.

What I am saying is that this technical change is a very, very difficult problem. This is a large-scale production process that is quite efficient at the moment. It does have a good product other than these defects we have been focusing on. We are contemplating here a massive industrial reallocation, and I don't believe it is going to be brought

about by a simple taxing scheme, or by the imposition of rigid standards. I think the Government will have to play a coordinating role, and I do think that it really goes far beyond antitrust. I don't think that is the only reason why.

Mr. SYMINGTON. Going back to your statement where you say under current competitive arrangement—

The role of Government—and of NASA if it is to be the Government's agent—is to aid in the technical choices, but even more to act as coordinator, to insure that technical developments have integral production and marketing plans, to referee an orderly transition.

I don't know whether that isn't getting into areas that one would prefer to leave in the private sector. It seems to me that if NASA has anything, it is a system approach to solving certain technical problems and some bright people working on them, and they ought to get to work on them after familiarizing themselves thoroughly with the problems the automobile industry has, and the kinds of things they do. I think you may have assigned Government the impossible task and you have given the industry the task that they seem to feel they can't meet either, if you can judge by their testimony; namely, the development of the engine.

Dr. STEINBRUNER. It is a very complicated situation. I think that much what you say is right. I think what we must recognize is that, first, if NASA is restricted just to doing technical developments—pure technology or just down line from that—it is not going to have much impact on the situation. That is the statement No. 1.

Second, the technical choices made about what designs actually will be produced for the American market now reside in Detroit. Those choices are made in a manner inevitably undervaluing the problems of emission control and fuel consumption. We cannot expect Detroit, realistically under current conditions or anything like them, to make the proper technical choices in these areas. The Government can force them to do things, but what they do as I think we are now seeing, we are not likely to like from a public point of view. I reach, I will admit, a very provocative conclusion which is far out and not likely to be embraced by the middle of next week by the Congress. I do this trying to flag what I think is a problem, a problem occurs in many other places in the economy. There are some fundamental technical choices which we must make, which do involve very serious public purposes, but which nobody at the moment really has the incentive or authority to make. There it is.

Mr. BROWN. Well, I would suggest that there are two possibilities which would make your suggestions feasible in the middle of next week. One, the Arabs to cooperate by cutting off our oil supply again and secondly, a lot of people in Washington, D.C. dropping dead from air pollution, in which case we would probably move rather quickly along the lines you suggest. I wouldn't be too sure one or the other might not happen.

Because we are constrained to answer the bell. Dr. Steinbruner, I shall have to adjourn the meeting at this time, but with your cooperation, we may wish to submit further questions.

Thank you very much for your very helpful testimony.

The committee will stand adjourned until the call of the chairman.

[Whereupon, at 12:25 p.m., the subcommittee was adjourned.]

ADDITIONAL MATERIAL FOR THE RECORD

STATEMENT OF

RICHARD S. MORSE
CHAIRMAN

SCIENTIFIC ENERGY SYSTEMS CORPORATION
Watertown, Massachusetts

Before the

SUBCOMMITTEE on SPACE SCIENCE and APPLICATIONS

Of the

COMMITTEE on SCIENCE and ASTRONAUTICS

U. S. HOUSE OF REPRESENTATIVES

June 1974

In 1968, as a member of the Commerce Technical Advisory Board, I served as Chairman of the Panel established by the Federal Government to study the auto emission problem in terms of technology and economics, with particular reference to the development of alternative solutions to the use of gasoline powered vehicles. Subsequent to the publication of this Panel's report, "The Automobile And Air Pollution: A Program for Progress," in 1967, I have been associated with several new developments which might offer solutions to the vehicle emission problem.

Scientific Energy Systems Corporation, of which I am Chairman and a Director, is a prime systems contractor to the Environmental Protection Agency under its program to develop a Rankine cycle steam powered auto. This program has been conducted by SES with Exxon, Chrysler, Bendix and Ricardo Engineers, Ltd. as subcontractors.

As President of the M. I. T. Development Foundation, Inc., a charitable corporation, organized and controlled by the Massachusetts Institute of Technology, I have responsibility for developing new and innovative mechanisms for expediting the transfer of technology resulting from M. I. T.'s vast research activities into public use. In this capacity and the result of my long time association with smaller research oriented industrial organizations, I have observed the extent to which

more innovative ideas are generated outside of the large corporate establishment. Ample support for this concept was developed during a study group of the U. S. Department of Commerce which resulted in the report, "Technological Innovation: Its Environment and Management, January 1967." As stated therein, the mercury dry cell, xerography, tungsten carbide, the jet engine, power steering, the Polaroid camera, Kodachrome color film, the ball point pen, F M radio, catalytic cracking of petroleum, the cotton picker, penicillin, were typical contributions of independent inventors and small organizations in the 20th Century.

More recent and significant developments in the automotive area, such as the low emission Honda engine, the Japanese and German Wankel, new Stirling engine developments in Sweden, Germany and Holland have, likewise, not come from the American auto industry, itself. This is not altogether unexpected, but rather is consistent with the pattern of other major industries which are primarily concerned with problems of production, marketing and return on investment.

The auto industry as a whole represents in many ways a unique component of our industrial society -- in terms of size and employment, of course, is a large proportion of our national GNP. The American

way of life, and to a growing extent our quality of life, is tied to the auto. Our highway system, on the other hand, is not directly funded by the auto industry, but rather by the State and Federal Government.

Environmentalists tend to be critical of our auto manufacturers because of their neglect in the emissions area. One should realize there have never really been financial incentives for the industry to either deal with this problem or that of fuel economy. Until recently the American public has preferred the large, chrome-plated vehicles and it is not yet clear as to how much a potential auto buyer is willing to pay for his own low-polluting car or one with low fuel consumption.

In most areas of our industrial economy, I see little reason for the government to become engaged in extensive research and development programs. There is, for example, little need for government funding for research work in support of the chemical and electronics industry inasmuch as the marketplace provides adequate incentives for industry to do its appropriate job. There are, however, exceptions to this general rule in such cases of national defense or in areas of public interest where the excessive capital or technical risks demand government action. I am afraid that the auto industry also falls in a special category where a well coordinated Federal R/D program is necessary if we are to most effectively solve the automotive emissions and fuel problems.

In the final analysis, it will be necessary for the present auto manufacturers to commercialize any new, improved propulsion or vehicle systems which may evolve from government support. I have no illusions as to the ability of the small company to become engaged in the mass production of passenger vehicles with the attendant problems of capital, facilities, distribution, servicing. Without a well managed and appropriately funded Federal R/D activity, some time will be lost in the adoption of our new ideas and the government, particularly from the viewpoint of its regulatory responsibility, will be unable to appropriately assess the state of technology. Only by such a national effort will it be possible to draw upon the best available resources found in our universities, industry and government.

In the President's February 10, 1970 message on Environmental Quality, he stated that:

> "I am inaugurating a program to marshal both government and private research with the goal of producing an unconventional-powered, virtually pollution free automobile within five years. I have ordered the start of an extensive Federal research and development

program in unconventional vehicles, to be conducted under the general direction of the Council on Environmental Quality."

Efforts to achieve this goal have been inadequate and no "extensive Federal research and development program" directed towards a "pollution free automobile" has been implemented. The present AAPS Program is definitely limited by budget constraints and has recently been substantially reduced in scope. I am unaware of Federal support for any new technology that offers the prospect for a really substantial reduction in fuel consumption in combination with "virtually pollution free" engine operation as the President said would be inaugurated under the general direction of the Council on Environmental Quality.

In spite of the relatively low funding level of the present AAPS Program, I believe that substantial technical progress has been made during the past year. This activity should be incorporated under the proposed ERDA Research Program where it can be more appropriately funded and integrated with other energy related R and D work.

With respect to HR10392, the Bill to authorize NASA to conduct research on ground propulsion systems, I believe that facilities and/or experienced personnel within the NASA organization <u>should</u> be employed,

when appropriate, to assist in an over-all R/D activity relating to ground propulsion systems. It should be, however, Federal policy to centralize all authority and responsibility for a total energy research program in one Agency, i.e., ERDA. We have already seen far too many Government Agencies endeavoring to get on the "Energy Bandwagon" in an effort to support people and facilities which, in some instances, may very well be unnecessary. In certain areas, NASA clearly has unique expertise and an established reputation. These resources should be called upon by ERDA in the same sense that corresponding resources of government and industry may be used in their integrated program. NASA has already served, for example, as a useful contractor to EPA, but the principal authority and responsibility, as in the case of the AAPS Program, has rested with EPA, itself.

In a recent Wall Street Journal article, I noted reference to the testimony of Donald A. Jensen, which he apparently gave before this Committee. This article stated that; "poor fuel economy is cited for scratching research on the steam engine," and Mr. Jensen said, "There are unresolved major problems which are also severe. We found the engine to be extremely complex with poor thermal efficiency."

I have very considerable respect for Ford Motor Company and the technical competence of Thermo-Electron Corporation which has

received financial support from Ford. Thermo Electron has also for some years been, in a sense, a competitor of SES and for the past few years has been one of the three EPA contractors developing Rankine cycle engines for use in automobiles. SES was recently selected by EPA as the principal contractor in competition with Thermo Electron and Aerojet General. I believe that the selection of SES was, to a large extent, a result of the simpler design which our company has evolved, its lighter weight, potentially lower cost and better fuel economy.

Neither Thermo-Electron Corp., nor Aerojet-General, in fact, used "steam" as referred to in the Wall Street Journal article. Both organizations employed an organic chemical which in vaporized form was used as a propulsion mechanism. The experience of SES -- and this would appear to be confirmed by its selection by EPA as now the principal contractor to the government -- suggests that pure water, i. e., steam as a working fluid has many advantages (with the exception of the freezing problem) over an organic chemical. Because of the thermodynamic properties of the organic chemical system, the size and weight of the engine, the vapor generator, valves, plumbing, feed pumps, and auxiliaries tend to be somewhat larger and heavier. The efficiency and, hence, fuel economy of any Rankine cycle engine is directly dependent

upon the maximum temperature of the working fluid. In the case of the organic chemical system, used by Thermo Electron and funded by Ford, there is an operating temperature limit imposed by the inherent instability and resulting decomposition of the organic fluid. In the case of true steam, temperature limitations are imposed not by the working fluid, but rather by other factors such as lubrication problems. The SES prototype 150 hp engine has been operating for some time at over 1,000°F. The weight per hp is approximately half that as reported by General Motors for their SE-101 steam car. Extensive full power dynamometer tests indicate that in terms of fuel economy, the SES steam system is now competitive with the automotive gas turbine and that additional development work should demonstrate its being competitive with the gasoline engine with, of course, greatly reduced emissions.

It is important to recognize that the favorable costs and reliability of the gasoline engine are a result of many years of continuous improvement. The Rankine cycle steam engine, in its present version utilizing modern technology, has yet to be even placed in production. In short, none of our so-called external combustion engines, such as the Rankine, Brayton, Stirling, or light weight diesels, have had the advantages inherent in decades of design, development and manufacturing experience.

In order to acquaint you more fully with the present status of the AAPS Program of EPA, I would like to enclose for the record comments of Jack Vernon, President of Scientific Energy Systems Corporation, which he presented at the EPA AAPS Coordination Meeting in Ann Arbor on May 10. All of the more detailed technical reports of this EPA activity are, of course, available to the public.

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__Degrees:__ S. B., Massachusetts Institute of Technology, 1933
Technische Hochschuler, Munich, Germany, 1933-34
D. Eng., Brooklyn Polytechnic Institute (Honorary), 1959
D. Sc., Clark University (Honorary), 1960

__Field:__ Technical Management, Research and Development

__Professional Experience__

1934 - 35 DIC Staff, M.I.T.
1935 - 40 Scientific Staff, Eastman Kodak Company
1940 - 59 President and Founder, National Research Corporation
Pioneered industrial applications of high vacuum technology.
Organized Vacuum Metals Corporation, Minute Maid Corporation and NRC Equipment Corporation
Chairman, Army Scientific Advisory Board
Member, Defense Science Board
1959 - 61 Director of Research and Assistant Secretary of the Army (R/D)
1961 - Distinguished Civilian Service Medal
U. S. Department of Commerce Study Panel on Innovation and Invention
Chairman, U. S. Dept. of Commerce Panel on Automotive Vehicle Pollution, "The Automobile and Air Pollution" 1967
Chairman, New England Council Committee on Science and Technology
Director, Research Analysis Corp.
Chairman, Advisory Board Air Force Systems Command

__Current Activities - 1974__

President and Director, M. I. T. Development Foundation, Inc.
Senior Lecturer, Alfred P. Sloan School of Management, M. I. T.
Vice Chairman and Director, Dresser Industries, Inc.
Chairman and Director, Scientific Energy Systems Corporation
Director: Compugraphic Corporation, Japan Fund, Inc., Rheocast Corp.
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Comments by Jack Vernon, President of SES

At the EPA AAPS Coordination Meeting

Ann Arbor, Michigan

May 10, 1974

It is a pleasure to be here, and I think it's a tribute to EPA and to the management of the AAPS program that these meetings are regularly attended by representatives of most of the companies in the automotive industry - both U.S. and world-wide. Also, at each Coordination Meeting there are always additional people sufficiently interested to come and listen to us describe our successes and failures. These are on display at each session, hopefully in a manner that maintains high credibility; and therein lies much of the value of the entire program.

Today, perhaps more than any previous meeting, you will hear some impressive things about Rankine cycle engines. I think this applies to data we have to present, and I believe it also is true for Thermo Electron, for the report on the California Steam Car Program, and for the Carters who, I believe, will be guest speakers this afternoon. They have achieved some remarkable results with their small engine in a VW squareback.

At the outset, however, let me make very clear that this is not to say any of us have all the answers. We certainly don't and "The Industry" doesn't need to worry that another "power" is about to enter the automotive lists.

But in the proper context, today's results are significant.

Consider, for example, that since the early 1900's Stanley, White, Doble, Bessler and GM has each done his or its thing - some better than others, but generally time has brought progress.

Consider, that the EPA AAPS Program is only 3 years old, yet real additional progress seems to have been made, continuing the trend toward improvements that can lead to a competitive engine. And there are some who might even argue that progress is being made at an accelerating rate.

Consider, finally, that none of the engine systems at present, by any stretch of the imagination, qualifies as a mature, end product of full-fledged development program. Each of players has been and still is operating on, relatively, a financial shoestring. And while the program started three years ago, engines have been running only a year and a half.

In this context, the program has been worthwhile, and we think SES has contributed something to state-of-the-art.

For those of you who are not familiar with our system, in a very few words it is a 4 cylinder, 135 cu. in., uniflow piston engine, in a 4600 lb. car using water as the working fluid and inlet steam at 1000°F and 1000 psi.

Exhibit 1

SES PROGRAM STATUS

SYSTEM PERFORMANCE HIGHLIGHTS

- FUEL ECONOMY - DEMONSTRATED 14.9 MPG AT 30 MPH

- EMISSIONS - WELL BELOW STATUTORY 1977 STANDARDS

The most significant item we have to report is a major improvement in fuel economy. We have demonstrated 14.9 miles per gallon at 30 mph, which is right on the projection we made in September, 1973 and presented at the last Coordination Meeting. When we went to press with this report, we had 95 steady state test points on the power map with the complete system running in our test cell on an engine dynamometer. But in addition, last week we measured losses on parts of system where design modifications are already underway. If we correct only for those measured losses that we know can be eliminated, fuel economy at 30 mph is 15.4 miles per gallon. We are quite confident that we can reach 18 mpg at 30 mph on the same size car by applying what we now know in redesigning the prototype engine.

The emissions goal of the EPA program is 50% of 1977 standards, and our results are below that EPA goal. I would like to point out, and make very clear, that our emission results are analytical projections of steady state tests, but with provisions for the effect of start-up, shut-down and transient operation.

Exhibit 2

SES PROGRAM STATUS

DEVELOPMENT TESTING

- ACCUMULATED TEST HOURS
  - SYSTEM TESTING (CURRENT BUILD 115) — 391
  - SINGLE CYLINDER — 847
    (OVER 30 HP 38)
    (RATED, 40 HP 2 1/2)
    (MAX SINGLE BUILD 200)
  - VAPOR GENERATORS — 2035
    (MAX SINGLE BUILD 905)
  - PROTOTYPE PUMPS — 3930
    (MAX SINGLE BUILD 600)

While there has not been nearly enough testing, the numbers indicate that this is no longer a paper engine. If one converts running time to miles, for example, we estimate that the present expander has logged about 15,000 miles, or the equivalent of five trips across the country. The testing program has accelerated in the last 6-8 weeks and we are now in a "test at will" mode where we can run 10-15 data points per day.

The 115 hours has been logged since March to collect test points on our current engine configuration. Again, I emphasize that this is a complete power plant.

We have put 300 hrs. on the single cylinder since the last Coordination Meeting in October. The 2 1/2 hours at 40 HP is not a lot of time, but it indicates progress in piston design, and that the engine can be operated over its full power range. Our plans call for more full power testing of both the single cylinder and the complete system over the maximum power envelope during the next several weeks.

The steam generator is pretty well shaken down with more than 900 hours on one unit. At a previous meeting we described tests we conducted to investigate tolerance to oil fouling. We added engine oil at the condenser and after 170 hours sectioned the boiler tubing to inspect it. We found minimal deposits, and overall results of that artificially severe test were highly satisfactory.

On the feedpump, the 3900 hours is total time on our prototype pumps. We now have 3 identical units and more than 600 hours on one of these - a single build with no modifications.

Exhibit 3

SES PROGRAM STATUS

SUMMARY OF RECENT ACHIEVEMENTS

- AUTOMATIC KEY START AT ROOM TEMPERATURE 19 SECONDS FROM KEY ON TO IDLE STEAM CONDITIONS OF 500 PSI AND 500°F.
- IMPROVED PISTON DEMONSTRATED 171 HOURS IN SINGLE CYLINDER UP TO 35 HP
- FREEZE PROTECTION DEMONSTRATION OF CRITICAL COMPONENTS
  - PUMP - CONDENSER - SUMP

We've made very good progress since the last meeting on the control system; it now requires just 2 driver inputs - key-on and power demand from the accelerator. We have produced idle steam in 19 seconds from key-on; we predicted 20 seconds at the October meeting. I would point our, however, that this was just a laboratory demonstration; the test loop was gasoline fired with the electronic control module, complete burner/boiler package, feedpump and throttle valve to simulate engine load.

We have been working on the 2 piece piston increase efficiency througl lower heat loss and to increase life. Testing on the single cylinder has gone very well thus far with good results.

Finally, we have successfully completed a series of tests to demonstrate capability of operation at temperatures below freezing. The test included only components, i.e., a condenser core section, insulated sump and feedpump; all were cycled through a cold soak at - 15°F, started and run, shutdown and recycled.

Although we certainly have long way to go, the results to date are encouraging and suggest that we're moving rapidly up the learning curve. They also give us reason to think that enough further improvement can be made to bring fuel economy into line with spark ignition engines - with emissions still well below the '77 standards.

STEAM AUTOMOBILE CLUB OF AMERICA, INC.,
Washington, D.C., June 17, 1974.

Hon. JAMES W. SYMINGTON,
Chairman, Subcommittee on Space Science and Applications, House Committee on Science and Astronautics, Washington, D.C.

DEAR CONGRESSMAN SYMINGTON: During your Subcommittee's hearings of June 11–13, you received testimony from Mr. Donald A. Jensen, Director, Automotive Emission Office, Ford Motor Co.

As reported in the attached Wall Street Journal story of June 13th, his testimony would lead both your Subcommittee and the public to believe that there was no future, automotively speaking, for steam power. The Steam Automobile Club believes it would be a very serious mistake to take Mr. Jensen's testimony at face value.

Tomorrow morning, June 18th, you will receive testimony from the J. W. Carters of Burkburnett, Texas. Their steam-powered VW Squareback Wagon is the first and only car ever to meet the original statutory emission standards set by the Clean Air Act Amendments of 1970. It is just these standards that the auto industry is now clamoring to have relaxed by congressional action.

The attached test data, obtained at the EPA laboratories in Ann Arbor, last month, raises very grave doubts about the credibility of Mr. Jensen's statements before your Subcommittee. The Carter car not only easily met the statutory standards; it also gave very respectable fuel economy—14.9 mpg—for a completely unoptimized, "one-off" car. This car has accumulated more than 4,500 road miles, has a top speed of more than 90 mph and operates precisely like the stock VW, including use of the standard 4-speed gearbox.

On the basis of their road and test experience, the Carters will welcome questions from you and your colleagues on any and all of the "problems" cited by Mr. Jensen in his appearance before you. We would also like to call your attention to the fact that the Carters developed this car without a penny of Federal funds and spent a tiny fraction of the $4 million cited in the article to have been spent by Ford and of the $26 million noted by EPA in their new release of May 24th announcing the Carter's test results.

Yours is not the first congressional committee to be told by Detroit that steam power has no future for the nation's motorists. From tomorrow morning on, we believe that the Carter's accomplishment guarantees that this argument will never again be taken seriously by the Congress or the American public.

Sincerely yours,

ROBERT L. LYON,
President.

[From the Wall Street Journal, June 13, 1974]

RANKINE ENGINE GOES WAY OF THE WANKEL AT FORD MOTOR CO.—POOR FUEL ECONOMY IS CITED BY CONCERN IN SCRAPPING RESEARCH ON STEAM ENGINE

Ford Motor Co., which recently scrapped research on the Wankel rotary engine because it didn't think the engine could get good enough fuel economy, has scratched the Rankine cycle steam engine off its list, apparently for the same reason.

It is estimated Ford put over $4 million into Rankine research, much of which was carried out with Thermo-Electron Corp., a Waltham, Mass., company that has been working on steam engines for some time.

"We found the engine to be extremely complex with poor theoretical thermal efficiency" which would "necessarily result in poor fuel economy," a Ford official told a congressional subcommittee in Washington.

Donald A. Jensen, director of Ford's automotive-Emissions office, said "There are unresolved major problems which are also severe. These relate to cooling, packaging, difficulty in obtaining projected cycle efficiencies and engine weight. Since these problems seemed to be of such magnitude as to make this power plant unattractive, Ford has discontinued its program." Mr. Jensen said much of Ford's "recent effort had been directed towards testing a model of a Rankine cycle engine in a Ford car to determine cooling air requirements."

In his testimony, Mr. Jensen also repeated Ford's previously announced position on the Wankel engine: It has a "poor thermal efficiency problem which has resulted in a fuel-economy penalty. As we have sought means to improve economy, we found the rotary engine to exhibit" higher emissions than other internal-combustion engines, he said.

Mr. Jensen was testifying before the House Space Science and Applications subcommittee, which was holding hearings on a bill that would give the National Aeronautics and Space Administration authority to develop new alternate ground propulsion systems.

Thermo-Electron said in Waltham it is continuing development of its Rankine cycle engine, but with new emphasis. "The emphasis for the past six months had been mostly nonautomotive, because we could see that Ford wasn't terribly interested" in automotive uses, Thomas Widmer, vice president, said.

Instead, Thermo-Electron is concentrating on "bottoming-cycle" uses, in which waste heat from another engine is used to heat the Rankine engine's boiler. For example, Nomikos Ltd., a London shipping company whose president is a director of Thermo-Electron, will install a Rankine engine on a small cargo vessel for testing. Exhaust heat from the vessel's diesel engine will feed the Rankine engine, which in turn will power a turbine to provide all the ship's electric power needs.

Carter Steam Power System—Description and Background

The Carters have taken a fresh approach to many of the problems traditionally associated with the steam-powered automobile. The expander is a four-cylinder, radial, single-acting uniflow without crossheads. It is designed to operate on 2,000 psi steam pressure at a temperature of 1,000 deg. F. Expansion ratio is fixed at an efficient 11.3 to 1.

Power modulation is accomplished by varying the boiler pressure and by the use of the standard four-speed VW gearbox. The expander produces more than 90 shaft horsepower from 35 cubic inches, at 2,000 psi steam pressure and 5,000 rpm.

The engine is not reversible, the gearbox being used for this function. Water and oil pumps are driven off the engine, as is the alternator; the engine is idled to handle the accessory load.

A blow-down feature is provided to shorten warm-up—which takes place in 20 seconds. Driveaway time is 30 seconds from turning the ignition key on a cold start.

The steam system is completely automatic: the car drives and operates exactly the same as the stock Squareback Wagon. Redundant features built into the control system prevent damage occurring to any of the parts.

Splash lubrication in the crankcase, along with an oil injector which feeds oil directly into the piston rings and cylinder, has been very successful. A special high-temperature oil made by Mobil Oil Company is used, as are channel chrome cylinders and cast iron rings. Bearings are pressure fed and are either ball, roller or needle. Crankcase temperature of 250 deg. F. boils off the little condensed blow-by that occurs.

The Carter system is completely closed. This means it is not necessary to continue to add water. The same water is used repeatedly. The condenser employs a vacuum under most conditions. On a 100 degree day, the condenser will maintain a pressure of −2 inches of mercury to 2 psig at 70 mph and −15 inches at 40 mph. Since the system is completely closed, the rings are virtually bathed in oil. The oil which escapes through the steam exhaust ports is not lost, as it would be is an IC engine, but is collected and separated by a small centrifuge. The cleansed, non-emulsifying oil is then pumped back into the crankcase, and the clean water is dumped into the makeup water tank.

The complete system fits into the VW Squareback Wagon's engine compartment, with the exception of a small ram air condenser, located up front. Weight of engine, feedwater pump, throttle valve, oil pump and filtering system is 114 lbs. Weight of the blower, boiler atomizer and automatic controls is 125 lbs. Including the weight of the condenser (made of lead and brass) and without making any special effort to conserve weight in this prototype, the total system weighs only 120 lbs. more than the stock VW's IC system.

The Carter steam car has been driven over 80 mph on several occasions, although its top speed would be in excess of 90 mph.

The car was first driven around Burkburnett, Texas on March 15th, 1972, and in two years has accumulated over 4,500 road miles, exclusive of many hours on the Carter's test stand and at test laboratories in San Antonio and Ann Arbor, Michigan.

This steam-powered VW is the first automobile installation, but many of the system components are fourth and fifth generation. In emissions tests conducted by EPA at Ann Arbor, the car easily surpassed the statutory levels originally set by the Clean Air Act Amendments of 1970. Based on the data pro-

vided by this test experience and known opportunities for relatively simple system improvement, it is anticipated that the next car will give emissions one-third of the statutory levels.

The same tests noted above resulted in fuel economy of 14.9 mpg, over a cold start on the 1975 Federal Driving Cycle and 17.3 mpg over the Federal Highway Driving Cycle. These figures are not especially impressive, but they do indicate the potential fuel economy which this system can achieve—with optimization. Based on present knowledge and test results, it is anticipated that this system can provide fuel economy equal to, or better than, that obtained by 1974 IC-engined cars. The second car is expected to give 25 mpg at 55 mph, better than 20 mpg over the Federal Driving Cycle and a driveaway time, from a cold start, of 15 seconds or less.

Mr. Carter and his son are both mechanical engineering graduates of Texas Tech University. Mr. Carter, Sr., is President of Texas Reinforced Plastics, Inc., a research and development company that develops fiberglass pipe and products for the oil and chemical industries. He developed the first successful glass filament wound rocket motor chambers for the Polaris missile system.

A summary of test results is attached for your information.

SUMMARY OF TEST RESULTS FOR CARTER ENTERPRISES STEAM CAR

	HC (0.41)[1]	CO (3.40)	NO_x (0.40)
Federal driving cycle:			
Run 1, 12.7 mpg	0.34	1.33	0.39
Run 2, 14.9	.40	1.08	.33
Highway (SAE) driving cycle:			
Run 1, 16.3	.04	.47	.32
Run 2, 17.3	.02	.28	.31
Steady state:			
20 mph, 18.4—2d gear	.05	.90	.29
20 mph, 21.8—3d	.28	1.18	.24
30 mph, 23.8—3d	.05	.41	.27
30 mph, 24.7—4th	.09	.65	.22
40 mph, 23.7—4th	.02	.24	.25
50 mph, 20.9—4th	.01	.16	.28
60 mph, 17.4—4th	.00	.11	.34

[1] The statutory emissions levels specified for 1975–76, by the 1970 Clean Air Act are: HC 0.41; CO 3.40; and NO_x 0.41—all in grams per mile. Since these standards cannot be met by conventional engines, they have been relaxed, by EPA action, and somewhat higher levels apply for the years in question.

Note: Only 1 set of steady state results shown for brevity; second set was strictly comparable.

Tests were conducted by EPA at their Ann Arbor facilities, during the week of May 6. Car was VW Squareback Wagon (weight 2,750 lbs). The car had accumulated approximately 4,500 road miles at test time. Fuel used was a blend of indolene and kerosene. The car is equipped with the standard VW 4-speed transmission.

FUEL ECONOMY —1974 MODEL YEAR TESTS

Make	Engine family	Model[1]	Miles per gallon
BMW	121	2002	21.1–22.6
	121 FI	2002 TII	18.1–20.3
British-Leyland (Triumph)	TB	TR-6	16.0–16.9
Fiat	132	124 series	16.0–17.7
Ford	2.0L white	Pinto-Capri	15.5–22.8
	2.3L white	Pinto-Mustang	16.7–21.0
GMC Chevrolet	101-1	Vega series	15.1–24.6
Mitsubishi	4G32	Dodge Colt, Plymouth Cricket	21.8
	4G52	Same	18.3–21.2
Nissan	4	Datsun 710 and pickup	18.5–20.4
	6	Datsun 610	19.5–20.6
Porsche	1	911 series	16.1–19.1
Renault	807	17 coupe	17.8–22.2
	841	17TL coupe, 12 ST wagon	17.5–22.2
SAAB	BC20	99	18.8
	BE20	99LE	19.4
Toyo Kogyo	Toyo 3	Mazda RX2-3	10.7
Toyota	18 R-C	Corona-Hilux	16.6
VW	2	Squareback	20.0–27.9

[1] All models having same weight, 2,750 lbs.

Source: EPA.

[From the Journal of Commerce, June 14, 1974]

RESPONDING TO PROTESTS—JAPAN MAY RELAX AUTO EMISSION STANDARDS

(By A. E. Cullison)

TOKYO.—Japan's Environment Agency may decide to relax or delay auto emission standards for 1976 in response to protests from the country's two largest automobile manufacturers that their present technology definitely will not allow them to meet the stiff requirements in time.

Both Toyota Motor Co. and Nissan Motor Co. have informed agency officials during hearings now under way in the Japanese capital that they do not feel it is possible to reduce the toxic pollutants by the deadline. However, Honda Motor Co. executives told the agency Wednesday they feel their firm can at least partially match requirements.

PROGRESS MADE

During testimony before the agency's specialists, the Honda executives claimed they will be in a position to develop technology which will enable the firm to cut back nitrogen oxide emissions to 0.6 grams per kilometer by the Spring of 1976. Agency officials said the figures provided by Honda are not sufficiently close to their target of 0.25 grams per kilometer but it is "a big move in the right direction."

Hideo Sugiura, Honda's managing director, was reported by the agency to have testified at the hearing that his company's compound vortex-controlled combustion (CVCC) engine is proving highly effective in cutting down nitrogen oxide emissions. He was confident, he said, that use of an emission gas recycling device, now in an experimental stage, eventually could drop the level to the required 0.25 grams.

But Mr. Sugiura was quoted by the agency officials as explaining Honda still has problems with fuel economy and driving performances and that it is impossible to provide an exact date when the strict agency standards could be met exactly.

Last Saturday the agency began conducting the hearings in the hope that the Japanese automobile makers would be able to meet the standards and that it will not be necessary to relax or postpone the 1976 emission requirements. Disappointment came early this week when Toyota and Nissan, Japan's two largest auto manufacturers, said they did not possess the technoolgy to do the job.

DEMAND MORE DATA

Agency officials said they plan to demand that Toyota and Nissan and other domestic auto companies provide additional data for review by the Central Pollution Countermeasures Council, and advisory organization of the agency. After such data has been examined, the agency said, it will be decided whether to go ahead with the strict standards or choose some other course, even to the extent of establishing new, but less stiff, interim requirements.

But automobile industry observers in Tokyo feel it would be highly unlikely that the agency will stick to its original plans for 1976, considering that only one of Japan's automakers feels even partially capable of meeting the standards in the desired time frame.

Executives for both Toyota and Nissan have appealed to the agency for a complete postponement of the implementation of the 1976 car exhaust requirements. Ryoichi Nakagawa, executive director of Nissan Motors, told agency officials on Tuesday, for example, that his firm had been working hard to develop a contract process and a low-pollution engine but it can't be done in 1976.

He said his firm could meet the 1975 standards which require nitrogen oxide emissions per kilometer to be reduced to 1.2 grams, but he insisted that the 0.25 requirement for 1976 was "out of the question in view of current technology which Nissan has available at this time."

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